Aalto University
School of Engineering

Data centers – threat or possibility to old industrial sites (brownfields) in Nordic countries

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Restructuring development is a constant process. In Finland restructuring has been extremely significant in the forest and ICT sectors in the recent years. In the forest industry restructuring has happened also in the other Nordic countries and other northern regions. After financial crisis, the international competition has become tougher which has forced companies to reorganize and relocate their functions to address fiercer competition. Due to this development many of the old industrial sites are now empty or with high vacancy rates in Nordic countries.

This thesis was concentrating especially on the ways to harness old industrial sites (brownfields) into data center use and to map the potential of data center investments in Nordic countries. Thesis introduces the concept of restructuring and explains how brownfield environments are born. In addition, study introduces the concept of data centers and describes the conditions needed for those facilities. This study analyzes also the current data center market and estimates how the market will develop in the near future.

There have been high hopes toward data center investments in the Nordic countries. Nordic countries have many characteristics that have been considered beneficial for the data centers (e.g. chilly climate, high political stability, reliable energy grid etc.). The potential of data centers has been identified extensively and they have been promoted by various ways (i.e. giving tax incentives, putting efforts on marketing and conducting fiber optic network improvements).

This survey consisted of both literature review and semi-structured interviews (thematic interviews). Total of 20 people were interviewed for this study. These people were representing different interest groups (e.g. data center operators, municipal officers and development companies). Interviewees came from Finland, Sweden and Iceland. Survey was conducted with the qualitative research methodology.

Old industrial sites (brownfields) can be harnessed for the data center use. However, those sites have to be high-quality in terms of the physical aspects, infrastructure and location. Nordic countries have excellent position of getting large data center investments in the future but circumstances have to be taken care with the constant improvements. Green energy and ecosystem solutions are the possible trends of the data center industry in the future. This study was conducted in the context of large data centers. The findings of the study cannot be fully generalized for smaller data centers.

Keywords Restructuring, brownfields, data center, Nordic countries

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Rakennemuutokset ovat koetelleet Suomen kuntia ja kaupunkeja viime vuosikymmeninä. Suomessa rakennemuutoskehitys on ollut viime vuosina poikkeuksellisen kiivasta erityisesti metsä- ja ICT -teollisuudessa. Metsäteollisuudessa rakennemuutostuulet ovat puhaltaneet myös muissa Pohjoismaissa sekä muilla pohjoisilla alueilla. Rakennemuutoskehitys on edelleen kiihtynyt kansainvälisen taantuman jälkeen, kun useat suuryritykset ovat tehostaneet toimintaansa ja siirtäneet toimintonsa ulkomaille tavoitellen parempaa kannattavuutta. Rakennemuutoskehityksen seurauksena useita teollisuuskäytössä olleita kiinteistöjä on jäänyt tyhjiksi tai vajaakäytölle – nyt näille kohteille etsitään uusia käyttötarkoituksia.

Datakeskuksille on asetettu suuria toiveita Pohjoismaissa. Suuret toiveet johtuvat osittain siitä, että Pohjoismaat ovat monilta ominaisuuksiltaan edullisia kohteita datakeskusten sijaintiympäristöiksi (esim. edullinen ilmasto, vakaa politiikka, luotettavat sähköverkot). Pohjoismaissa datakeskuksista on toivottu sekä alueellisia että kansallisia talouden piristysruiskeita. Hankkeiden potentiaali on maissa hyvin tunnistettu ja niitä on pyritty edistämään erilaisin toimenpitein kuten verohelpotuksin sekä investoinneilla maiden omaan kuituverkkoinfrastruktuuriin.

Tässä diplomityössä selvitettiin vanhojen teollisuuskiinteistöjen potentiaalia datakeskuskäytössä sekä Pohjoismaiden yhteistä potentiaalia houkutella datakeskusinvestointeja tulevaisuudessa. Diplomityössä pohdittiin myös rakennemuutosta ilmiönä, perehdyttiin brownfield-kohteiden syntyyn, esiteltiin datakeskusten tekniikkaa sekä perehdyttiin datakeskusten yleisiin vaatimuksiin. Työssä analysoitiin myös datakeskusmarkkinan kokoa sekä pohdittiin alan tulevaisuuden kehitystä, trendejä ja mahdollisuuksia.

Tutkimus toteutettiin kirjallisuuskatsauksena ja empiirisenä tutkimuksena. Empiirisessä tutkimuksessa tiedonkeruumenetelmänä olivat teemahaastattelut. Diplomityön tutkimusote oli kvalitatiivinen. Puolistrukturoituun haastattelututkimukseen osallistui yhteensä kaksikymmentä datakeskusalan asiantuntijaa. Asiantuntijat tulivat Suomesta, Ruotsista sekä Islannista.

Tutkimuksen mukaan vanhat teollisuuskiinteistöt soveltuvat datakeskustoimintaan, mutta vain osa kiinteistöistä on laadultaan, sijainniltaan ja rakenteeltaan sellaisia, että niillä on potentiaalia datakeskuskäytössä. Pohjoismailla on erinomainen mahdollisuus saada datakeskusinvestointeja tulevaisuudessa, mutta hankkeet vaativat jatkuvia panostuksia erityisesti sähkö- ja kuituverkkoihin sekä markkinointiin. Tulevaisuudessa vihreä energia sekä ekosysteemiajattelu ovat mahdollisia datakeskusalan trendejä.

Avainsanat Rakennemuutos, brownfield, datakeskus, Pohjoismaat

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This Master's thesis has been made together with Stora Enso Oyj and it is a final step in my graduation process. The idea for this master's thesis came from the actual need and the company's interest toward the topic.

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During this seven months which I have been doing my thesis I feel that I have learned so many new things and new ideas which are going to give me a big boost for my forthcoming years. While working with my thesis I also met many interesting people who I have been able to share thoughts and ideas. I have to thank all of my interviewees for taking part of my interviews. Your attitude toward my thesis has been amazing and I am very thankful for all of you, equally. I hope you will benefit from my achievement.

The journey is more important than the destination and reaching one lead to another one…

In the sunny Espoo,

Tuomas Toivonen

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Terms and Definitions

Big data	Great amount of data being impossible to handle with traditional data collection methods.
Brownfield	Term used in urban planning. Means the land previously being used for the industrial purposes. Term is used different ways in different countries since it has no common international definition. Definition in the empirical part of this study: *Old industrial site with no contamination or very light contamination. Existing buildings having good condition with no need for major renovations (i.e. old paper mills)*
Billion	A thousand million (1,000,000,000). Nowadays the figure refers to a thousand million in both American and British English (see Oxford Dictionaries 2016.)
CaaS	Computing as a service. Is often referred only as "cloud". It is a collection of different computing resources from applications to data centers which are used over the Internet with the basis of pay-for-use (IBM 2015.)
Creative destruction	Term invented by Joseph Schumpeter. Was used in his book "Capitalism, Socialism and Democracy (1942). In the creative destruction the new model constantly replaces the old structure and creates new (Investopedia 2016.)
Data center	Facility housing plenty of computers and IT equipment.
Free Cooling	Method of using the outside environment in the data center cooling. Is used to reduce the power consumption in the data centers. Different free cooling methods can be divided into three categories: Air-side cooling, water side cooling and heat pipe free cooling (Zhang et al. 2014.)
Greenfield	Has no specific definition. Generally understood as a site with no previous development, mineral extraction or contamination by waste disposal (Glumac et. al. 2013 p. 796).
Latency	The term latency is used to describe the time between the stimulation and response. In general it is used to describe the time used for a packet to travel from the place A (sender) to place B (receiver) (Webopedia 2016a). In fiber optics latency is largely understood as a speed of light. However, that is only theoretical and the speed of light is actually lower in the fiber optic cables (O3b Network 2011). Latency is measured in milliseconds (ms).
Megatrend	Megatrends are trends that have a great influence on the future development. They are kind of big development lines which have global level influences (Toivonen 2011 p. 29). They are often seen as big processes of change having impact on social, political and economic development (Futurix 2005).

Middleware	Describing separate products being the "glue" between two applications. It is a software that connects two sides of an application and shares data between them (Webopedia 2016b.)
Old industrial site (Brownfield)	In this thesis context used as a synonym for brownfields. Examples of old industrial sites are paper mills, machine shops and assembly rooms.
Silent restructuring	Restructuring happening in the SMEs. Often gets very little public attention compared to restructurings in large companies (Voss 2007 p. 17).
Purchasing Power Standards (PPS)	Artificial currency unit used by Eurostat. With One PPS one should theoretically be able to buy the same amount of goods and services in each country. PPS can be derived from any economic aggregate in a national currency by dividing it with its respective purchasing power parities (PPP). (Eurostat 2014)

Terminology

PUE	Power Usage Effectiveness
ÄRM	Äkillinen rakennemuutos (Sudden structural change)
CRAC	Computer room air conditioner
TCP	Total cost of ownership
SME	Small and medium-sized enterprise

1 Introduction

This section (part I) starts by introducing the background of this study. Then the research problem and objectives for the research are described. After that the scope of the research is described with the methodology of this research. At the end of this section research methods are briefly described. This section ends for the description of the general structure of the study.

1.1 About the background

The background of this thesis is told from the perspective of one Nordic country, Finland. Restructuring development in the Finnish industry (especially forest and ICT industries) has created some empty industrial space in the past few years. This thesis tries to find alternative future uses especially for those sites. However, the scope of this thesis is to understand old industrial sites (brownfields) potential in data center use – not just in Finland but in all the Nordic countries.

The restructuring development in Finland has been significantly noticeable in the recent years. This development makes Finland an excellent example of introducing what restructuring development can cause and how flourishing industrial sites can turn empty in the short period of time. The same kind of development has however, occurred also elsewhere in the world and among other Nordic countries.

1.2 Background (and Motivation of the Research)

European economy seems to have recovered from the financial crisis and GDP rates in the countries have shifted into positive. Nordic countries seem to have quite moderate growth rates except Finland. Finland seems to have been falling behind from the other Nordic countries and the rest of Europe (Eurostat 2015). This development has caused some uncertainty and predicts hard times for the country in the future. The Bank of Finland (2015) is expecting that GDP of Finland grows 0.2 % in 2015, 1.2 % in 2016 and 1.3 % in 2017. These GPD growth rates are lot behind the other Eurozone (European Commission 2016a; Wikipedia contributors 2016a; Eurostat 2016a).

Situation in Finland has been extremely hard since the supply of the labor has decreased, investments are small and many companies are facing difficulties and lowering their R&D costs (Kilponen et al. 2014). The new Finnish government and the Prime Minister Juha Sipilä have tried to find solutions to improve the productivity of Finland by releasing so called *a social contract*. The main goal of this contract is to boost the competitiveness of Finnish work to make it competitive with other Nordic countries and its competitors in Central Europe and at the same time change the negative direction of Finnish economy. Despite many tries, the social contract is still in the headwind (situation in the beginning of 2016). Still, not only political acts will solve the problems of Finland and there is a true need for new businesses. In this thesis data centers are presented as one of the future business possibilities which could bring international investment to Finland but also to other Nordic countries.

Downward in Finland began after the international financial crisis in 2008 which influenced European and Finnish economies very dramatically. The biggest influence of the crisis on

Finnish economy was that the international trade reduced substantially and there was no more demand for the export products of Finland because people all over the world reduced their consumption. This caused a big drop in the Finnish GDP together with many other European and Nordic countries (BoF Online 2011 p. 7-17.) However, most of the European countries found fairly quickly a new growth path after the financial crisis while Finland still struggles with the low growth rates (European Commission 2015 p. 154).

International financial crisis and recession accelerated the restructuring in the Finnish industry. Especially it changed the global business environment the way which maintains the restructuring process by increasing the global competition and lowering the international demand. This development caused pressure for companies to enhance their business by closing factories or relocating their businesses to the new markets (BoF Online p. 43-50.) Still, this development has happened everywhere around the world, not just Finland.

Restructuring in Finland has been especially significant in the traditional industries like paper and forest industries but also in the ICT sector (Työ- ja Elinkeinoministeriö 2016a; Yle Uutiset 2014a). Nevertheless, restructuring in Finland is not just a consequence of financial crisis and the restructuring development started already prior to the crisis. On the other hand financial crisis accelerated restructuring development and forced companies to reduce their production to the level of diminished demand. Due to restructuring the structure of the economy in Finland has changed more service oriented and it is possible that the significance of the industry will no more scale to the same level prior to the crisis (BoF Online 2011 p. 46.)

Also, restructuring has caused another problem in Finland: due to scaling down the industrial production, many of the factories and production facilities have to been shut down. As a result of the development, there are now plenty of old industrial buildings and factory halls which have no more any user and usage.

Still, it is good to notice that restructuring development has not just occurred in Finland and country is used in this thesis only as an illustrative example. Same industries in the other Nordic countries have been under restructuring development too and paper mills have also been closed in Sweden (Euwid 2013). Similar restructuring development has, however, happened in the past and will happen in the future all around the globe and among all industries. In fact restructuring development is more or less a constant process taking place everywhere and all the time.

This thesis tries to find ways how empty factories or production halls in his thesis called old industrial sites or brownfields could find alternative uses in the future. One of the possible future scenarios is to harness those sites or facilities into data centers for the domestic or international data center operators. This kind of development has in fact already been realized in the recent years among Nordic countries (see Nissilä et al. 2015).

Data center operators have in fact harnessed old industrial sites (brownfield) for their data centers all over the world. Finland and other Nordic countries have also got their share of those investments. A good example of the described development is Google's date center investment in the old paper mill in Finland in 2009. Also other Internet service producers in addition to Google are searching sites from Europe which gives Nordic countries a possibility to lure more those investments.

Finnish previous Minister of Economic Affairs Jan Vapaavuori says that data center investments have been much desired in Finland and Finnish government has done persevering work to lure data centers in Finland (Talouselämä 2015). One of the Finnish government's recent actions was to lower the electricity tax of the data centers on the same level with other industries (Työ- ja Elinkeinoministeriö 2016b; Elinkeinoelämän keskusliitto EK 2014). Those efforts seem to be paying back and other data center operator are following the Google's example and investing in Finland (see Talouselämä 2015; Yle Uutiset 2014b; Daily News 2014; Työ- ja Elinkeinoministeriö 2015a). Now Sweden has also plans for lowering the energy taxes for data centers[1] (The Power Region 2015; Data Center Knowledge 2015; Bohlin et. al. 2015 p. 315).

The amount of Internet users and data use has been in a constant grow. The use of Internet and amount of data have grown rapidly and the need for data to be stored and processed in the "big data" storages (data centers) has grown (Nissilä et al. 2015 p. 8). Traditionally enterprises and governments have been running their own data centers but nowadays many companies have shifted into using third-party data centers to take care of their computing needs. There are also big Internet service producers needing huge data centers for hosting their Internet related services (Savolainen 2013 p. 2-4, 21-25).

The interest toward data centers has faced a boom in Nordic countries. In Finland for example many politics have been actively promoting data center investments. An illustrative example of the described activity is that when Google announced its data center expansion in Hamina in 2013, Finnish Prime Minister then Jyrki Katainen was the one announcing the news (Nissilä et al. 2015 p. 13). Big interest toward data centers has occurred also in other Nordic countries. In Sweden, for example they have identified "shovel-ready" sites in ten different regions around the country to ease data center operators to start business in the country. Big energy and fibre optic network operator companies have been also supporting those efforts (DCS Europe.)

There are various reasons why data centers are seen as a big business possibility for Nordic countries. Even the international competition is fierce, Nordic countries have some advantages, one of the often highlighted being chilly weather which enables "free cooling solutions". The cheap electricity, reliable energy grids and stable political climate are other often mentioned characteristics while speaking about the strengths of Nordic countries (Bohlin et. al. 2015 p. 315-316.) Nordic countries have enjoyed high positions also in the international data center rankings. The Data Centre Risk index (2013) ranked all Nordic countries (except Denmark) among ten best countries in the world in its annual ranking[2]. This index evaluates the risk related to the data centers in the 30 most important global data center markets (see Data Centre Risk index 2013).

Positive feedback has come also in the form of investments. Large Internet companies like Google, Facebook, Yandex and Microsoft have opened their data centers in Nordic countries together with many smaller data center operators. According to German data center operator Hetzner Online AG they chose to place their new data center in Finland because of the

[1] Role of electricity tax is discussed in the Chapters 2.7.2 and 4.4.1

[2] Denmark was not evaluated in the index.

following reasons: Chilly weather, a stable electricity grid, low electricity prices, a new undersea cable (C-Lion) and the proximity of Russia (Työ- ja Elinkeinoministeriö 2016b).

Mittal (2014 p. 2) says that modern data centers are typically big facilities containing up to tens of thousands servers and providing services 24/7 to hundreds of thousands of users. This size scale is far from the times when the data centers were only small hidden rooms locating in the basements or closets of the companies. Traditionally data centers have been located in the financial and business centers in the world. In Europe it has meant that data center operators have built their data centers to London, Paris, Frankfurt and Amsterdam. These cities are still enjoying the growth in the data center market (CBRE 2014). However, central location is no more everything for all the data center operators in the data center industry and clients can be serviced also behind the longer distances.

Nowadays some companies have started to build their data center facilities in the remote places. This development has been a trend especially among the big Internet service producers constructing large scale data centers. Savolainen (2013 p. 14, 25-26) explains that the trend of constructing data centers in remoter places has been a result of three factors: 1) Data centers have grown in size and require more space than before, 2) Data centers require ever-greater amount of power which can be no more satisfied in the metropolitan areas and 3) Data centers have become highly automated facilities requiring less on-site workers. By considering those factors, it is quite inevitable development that big data center facilities have been located to more remote places where all those three requirements can be fulfilled.

A trend of locating large data centers to the remote locations is good news for Nordic countries which are all sparsely populated and have plenty of free land waiting to be harnessed. Also, region shares many desired characteristics of data centers such as stable environment and politics, chilly climate and good energy and fiber optic infrastructure just to name a few. The potential of the region to attract especially big data centers can be considered promising.

In this thesis there are two primarily targets. One is to estimate the potential of old industrial sites (brownfields) in the data center use and another to find out different ways how brownfield environments could become more interesting among data center investors. The secondary goals of the thesis are to estimate the general circumstances for data centers in the Nordic countries and to find out which kind of actions could increase countries' position in the competition of new data center investments. In this thesis the future trends of data center industry are also analyzed and their importance in the future discussed.

There was very limited amount of prior academic research about the data center possibilities in the brownfield environment. The amount of academic research about the different uses of brownfield sites was also very limited. Still, there were some white papers of different organizations evaluating data center possibilities in the Nordic countries which were used to create the basis for the research.

1.3 Research Problem and Objectives

"According to old proverb, good question is already half of the answer" (Hirsjärvi et al. 2009 p. 125).

Hirsjärvi et al. (2009 p. 125-126) say that setting a research problem is usually way more complicated than solving it. By considering that fact, research question should be well thought out before collecting the material for the actual research. However, this kind of approach is not the whole truth in the qualitative research. In the qualitative research the research problem takes its shape often during the research process – not before. Often, instead of speaking about the research problem, the word "research task" is used in the qualitative research, which sets the objectives for the research in a more general level.

As described in the background earlier, the interest toward data centers has been increased in the recent years. Especially the chilly temperature in the northern regions and its benefits for data centers cooling have been the driving factors why there has been a growing interest toward data center industry possibilities in Nordic countries.

One of the purposes of this thesis was to investigate, if those high expectations toward new data center investments in Finland and other Nordic countries are completely realistic and what are the factors which can contribute those data center investments. Even the research is done by considering the possibilities in Nordic countries, some of the findings can be generalized for the other northern regions and countries sharing similar conditions. Similar condition means in this research context characteristics like chilly temperature, cheap electricity, stable bedrock and stable political climate.

There is very limited amount of previous academic research about the thesis topic. Still, some studies have been conducted about the previous data center investments in Nordic countries. Two big Internet service producers Facebook and Google for example have conducted their own reports "*white papers*" and investigated data center potential in Nordic countries. These reports form a good picture about the data center business in Nordic countries and explain the effects of the two biggest data center investments in Nordic countries (see Nissilä et al. 2015 and Clipp et al. 2014). Nevertheless, there has been no previous research targeting interest especially to the old industrial sites (brownfields) and their potential in the data center use.

The development in the data center industry is also fast-moving business so different trends and technologies can change even the potential of different regions in a short period of time. Not only the technology but also changes in the data security legislation and taxations can affect on the potential of different countries even in a short timeframe. This is why the research concentrates also on finding the different trends of the data center market.

To achieve the goals set for this research, the following research questions were set to guide the research:

Research question 1: Are old industrial sites (brownfields) good locations for data centers?

Research question 2: How can Nordic countries get their share of the data center investments?

- **Sub question 1:** What are the advantages and disadvantages of Nordic countries compared with the rival countries?
- **Sub question 2:** How should these investments be promoted in Nordic countries?

Research question 3: What are the trends of data center industry?

The first research question tries to clarify the possibilities of opening data centers in the environments having previous history in the industrial use. This is an interesting question especially since the need for data center sites has grown when many of the "old industries" have decreased or ended their functions in many Nordic countries. Research question tries to answer the question, why many industrial sites have not risen greater interest among data center operators and most of the new data centers have been made in the greenfield sites.

The aim of the first research question is also to find ways how old industrial sites should be promoted to data center operators to increase their interest in them. Research question also tries to clarify what is the potential of brownfield sites in the data center use and who are the most potential clients: for example if the most potential clients are huge cloud service providers or if the target group for brownfields should be searched among a bit smaller operators or from colocation solution providers.

The second research question was chosen since there have been big expectations of getting data center investments in Nordic countries, as described in the background. The key idea of the research question is to identify the main advantages, but also the disadvantages of Nordic countries in the data center industry context. Research question also tries to find ways how data center investments should be promoted in Nordic countries to make the region more attractive.

Although some of the advantages of the region have already been identified in the previous academic literature, the second research question can still be considered very important. Research question not only tries to identify the different strengths or weaknesses of the region but also to find ways how those factors could be used in the promotion of the region. The main focus of the research question is to find ways how Nordic countries can attract more data center investments in the future and answer to the growing competition among other countries.

Third research question takes a look at the current trends of the data center industry. It also tries to identify "experts' visions" of the key drivers of the industry in the future by identifying the future trends of the data center industry. Research question should give Nordic countries and Nordic companies new information about the ways how to answer for the future demand and enable conditions that are vital for the data center investment.

The results of this study will benefit many instances. Research will give topical information about the current circumstances of the Nordic data center market and introduce some of the data center industry trends of the future. For the regions facing restructuring development, the thesis will give useful information about the possibilities (=one potential way) of using old industrial sites (brownfields) in the future[3]. For the companies having old industry halls or other facilities the research should give one optional way how those real estates can be used in the future.

[3] Especially considering the data center use.

1.4 Scope of the Research

This thesis investigates the possibilities of locating data centers in old industrial sites (brownfields). The data center investment possibilities are analyzed in one data center market region (Nordic countries) and especially in the example country, Finland. Study focuses especially on the large data centers (mega data centers) environment. [4] This strategic decision of concentrating primarily on the large scale data centers was made based on the previous literature and assumption of different requirements of different sized data centers: It was assumed that small data centers are often built close to the market and customers when large scale data center operators are searching sites from much wider geographic area (reasons for that kind of behavior can be found from Chapters 2.6.10 and 4.4.2).

The main focus of this research is to understand the possibilities of old industrial sites (brownfields) in the data center use. Those sites where defined in this research context as following:

> *"Old industrial sites are sites that have been in the industrial use but have no significant contamination or the contamination is very low."*

This definition is rather different to, how brownfield sites are commonly understood in the U.S., where the term "brownfield*"* has its origin (See Chapter 2.4.1). Still, the definition used in this study is not very far from the definition used in many European countries (EU has, however, no common definition for brownfield sites) (see Chapter 2.4.1). Since this thesis was conducted in this special context, results are not generalized for all types of brownfield sites. Narrow definition enabled to concentrate on the typical brownfield environment in the Nordic countries since other types of brownfields did not have to be taken into account. This thesis definition for brownfields corresponds to typical old industrial sites in Nordic countries. The illustrative examples of sites this kind are old paper mills and ICT manufacturing halls being relatively new or lately renovated.[5]

There are also geographical limitations in the thesis: Data center market potential and data center industry possibilities are analyzed in the context of Nordic countries. The Nordic data center market was considered very homogenous, and therefore it was treated as one single market in this thesis. This limited market (Nordic countries) sets limitations for generalizing the results for the larger geographical regions. Metsämuuronen (2006 p. 212) says that generalizing in the case studies (which this study due to strict definition for brownfields is) is not a common practice. He continues that maybe case study should be seen more as a small step toward in generalizing and generalizing should not be an end in itself. In this study, the case study approach is used even the study takes place in a slightly broader environment (not just one brownfield site) than what is typical for case studies.

The idea for the thesis topic has come from the Finnish forestry corporation Stora Enso. The company is searching alternative uses for their old industrial sites which have no more use in their own core business. The interest of the company was taken into account in defining the brownfield definition.

[4] Data centers bigger than 5 MW were considered as mega data centers in this thesis.
[5] In some cases also old military bases can be in accordance with the definition.

1.5 Research Methodology

Hirsjärvi et al. (2009 p. 66-88; 125-138) say that often the hardest part of in the research is to make the decision "what are we studying and how are we going to conduct the study?" Those are fundamental decisions having a great impact on the whole research. Those questions also determine what kind of results we can expect to get (from the study). When we choose a research method (e.g. interviews) for our research, we can be sure that the research would have been completely different when using a different research method or research strategy (qualitative or quantitative). However, even the research would be different in many means, it is impossible to say whether some research method is better than the other for conducting that particular research. Different research strategies can also give results of same kind so many kinds of research practices can actually lead to the desired outcome.

According to Hirsjärvi et al. (2009 p. 124), research has a strong foundation when researcher has made compatible (coherent) selections in all the following four levels: problem setting, the philosophy of science, research strategy and in the theoretical understanding. All these aspects are somehow taken into account in every research even the researcher might not be aware of making such decisions.

Purpose of the research
This thesis is closest to be exploratory study in its nature: The amount of the existing theories of the research problem was very limited. Limitations in the existing theory came out during the material collection for the thesis. In fact there was a great amount of existing research about the data centers and their technology, but lack of theories which were addressing with the issues like: The potential of Nordic countries in the data center business or how data center fit into brownfield sites – which are the main interest areas in this research. Still, one relatively similar research has been conducted before: Antti Savolainen (2013) was studying in his master's thesis the strategic investment criteria for mega data centers in a small town in Finland. In addition to investigating the weights of different factors affecting the investment criteria of mega data centers, Savolainen also evaluated somewhat the efforts of Finland for getting data center investment and the possible trends of the data center industry. Despite the relatively similar research approach, the findings of Savolainen were not used to formulate hypothesis for this research. All the other previous studies were considered also being too far for enabling the formation of the hypothesis for this research.

Since no hypothesis was formulated, the survey is considered as explorative research. Still, the study also has some characteristics of the futures studies because it explores the future trends of the data center industry. Nevertheless, no techniques of futurology are used and investigating the future trends is only one of the three different themes of the research.

Research strategy
This thesis uses an empirical research methodology. The research strategy is similar to a case study since the research problem is analyzed in one market context and also the definition for the brownfields is different to the average (see Chapters 1.4 and 2.4.1). Hirsjärvi et al. (2009 p. 134-135) describe that case study approach fits studies that are searching detailed information about one single case or small group of different cases being related to each other. Typical for these kinds of studies are the use of multiple research methods: typical research methods in the case studies are e.g. observation, interviews and document analyzing. Nevertheless, this study approach to the (research) problem is a somewhat wider than how Hirsjärvi et al. (2009) describe the typical case study approach: There are, still,

other characteristics (e.g. narrow brownfield definition, considering only the Nordic data center market and interviewing the certain "small" group of people) which make the study closest to be a case study in its nature.

Study uses qualitative approach which Hirsjärvi et al. (2009 p. 138) name a typical strategy for explorative research. The basis of the qualitative research is to find answers for the real life (problems). Qualitative research also tries to understand and investigate the research subject with multiple ways and achieve comprehensive understanding about it. However, with the qualitative research we are not achieving the real objectivity since the researcher and his previous knowledge have influence on the achieved results. Qualitative research is more likely to reveal and find facts than confirm them.

Research method
The main research method (thematic interviews) was chosen not just by taking into account the previous research and the research methods there, but also by having a strong vision that the chosen research method will benefit the objectives of this research the best (see Chapter *1.6 Data Collection and research methods* for more detailed information about how research methods were chosen).

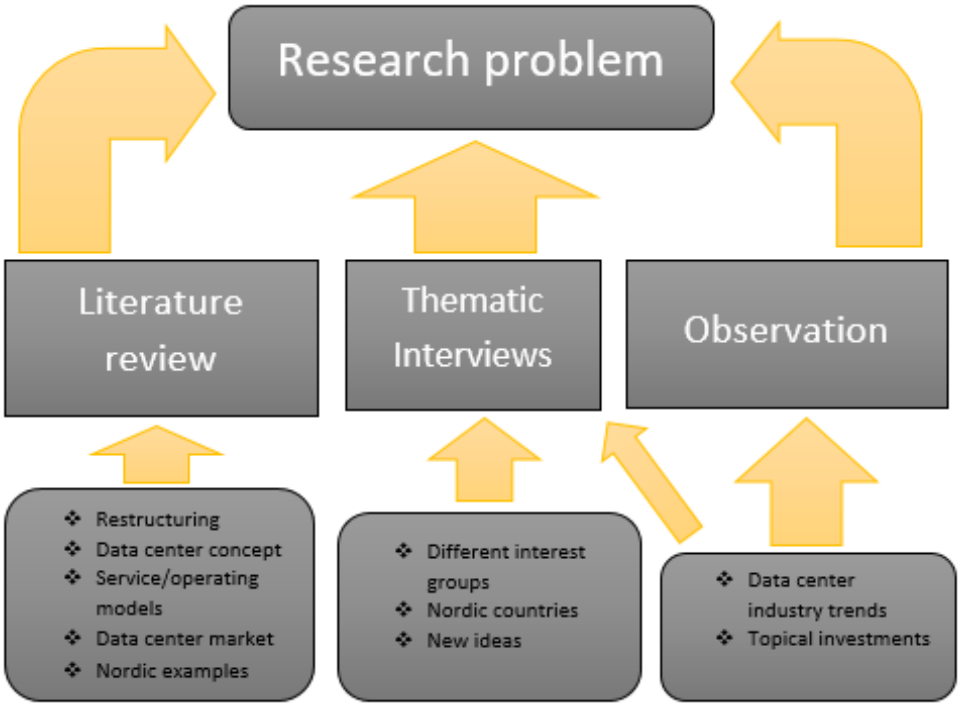

Figure 1: Research methods. Observation was used to support other research methods.

This thesis is carried out by combining the results of a literature review and semi structured or so called thematic interviews (this is how Hirsjärvi and Hurme (2006) call this interview method) as a research methods. The third research method used in this thesis is observation. Research methods used in this thesis are shown in Figure 1. In this research, observation was done by following IT -magazines but also other media describing data center and IT industry development. Observation was done during the whole research process since it (=the use of method) was supposed to give up-to-date information about the development of data center industry (see next chapter).

1.6 Data collection and research methods

This thesis is conducted by using total of three research methods: Literature review, interviews and observation. Two main research methods are literature review and semi-structured interviews (thematic interviews). The third research method, observation was used as a supportive method for interviews and for getting up-to-date information about the data center market. Observation was also used to compare scientific literature with the less formal magazines and the general discussion related to data center industry in the media.

Literature review is based on the existing scientific literature about the thesis topic. It gives the reader a fundamental understanding about the research problems and introduces the basis for the empirical study. Literature review concentrates on giving the reader the basic understanding about restructuring, brownfields, data centers and the data center industry and market in the world and in the Nordic countries. The technology solutions of data centers are not described by giving the reader very detailed information about different data centers technology solutions. The approach of the literature review is practical and instead of presenting widely data centers technology, it gives the reader understanding of data center industry in general and data centers importance for our society.

Observation was used as a supportive research method for the other primary research methods. Observation means in this thesis that data center industry was closely followed during the working process and observation was done throughout the (whole) working process. Observation was made also by following actively different media and by trying to note the changes in the industry. There was also intention to take part in the different data center industry events, but unfortunately the time frame of the research did not make it possible.

The main research method in this thesis is semi-structured interviews (also called as thematic interviews). More information about the interviews can be found in the Chapter 3.2. Semi-structured interviews were used to create new information about the topic and to answer the research questions. Interviews were used as the main data collection method in this thesis.

1.7 Structure of the study

This thesis consists of 6 different parts visualized in Figure 2 (mind map of the thesis structure is presented as Appendix 3). First part of the thesis (part I) is the introduction. Introduction presents the background of the research and introduces the research methodology, research methods and the general structure of the thesis. In Addition the scope of the study is presented in the introduction part of the study.

The second part (part II) of this thesis is a literature review. Literature review gives the basic understanding about the restructuring, the born of brownfield environments and the brownfield development. It also introduces the concept of data centers and makes a reader aware of data centers common characteristics. Literature review delivers the answers i.e. for the following questions: What are data centers? What is important in the site selection of data centers? And what are the service models of data centers? In addition literature review delivers information about the data centers potential and gives two Nordic examples of different data centers.

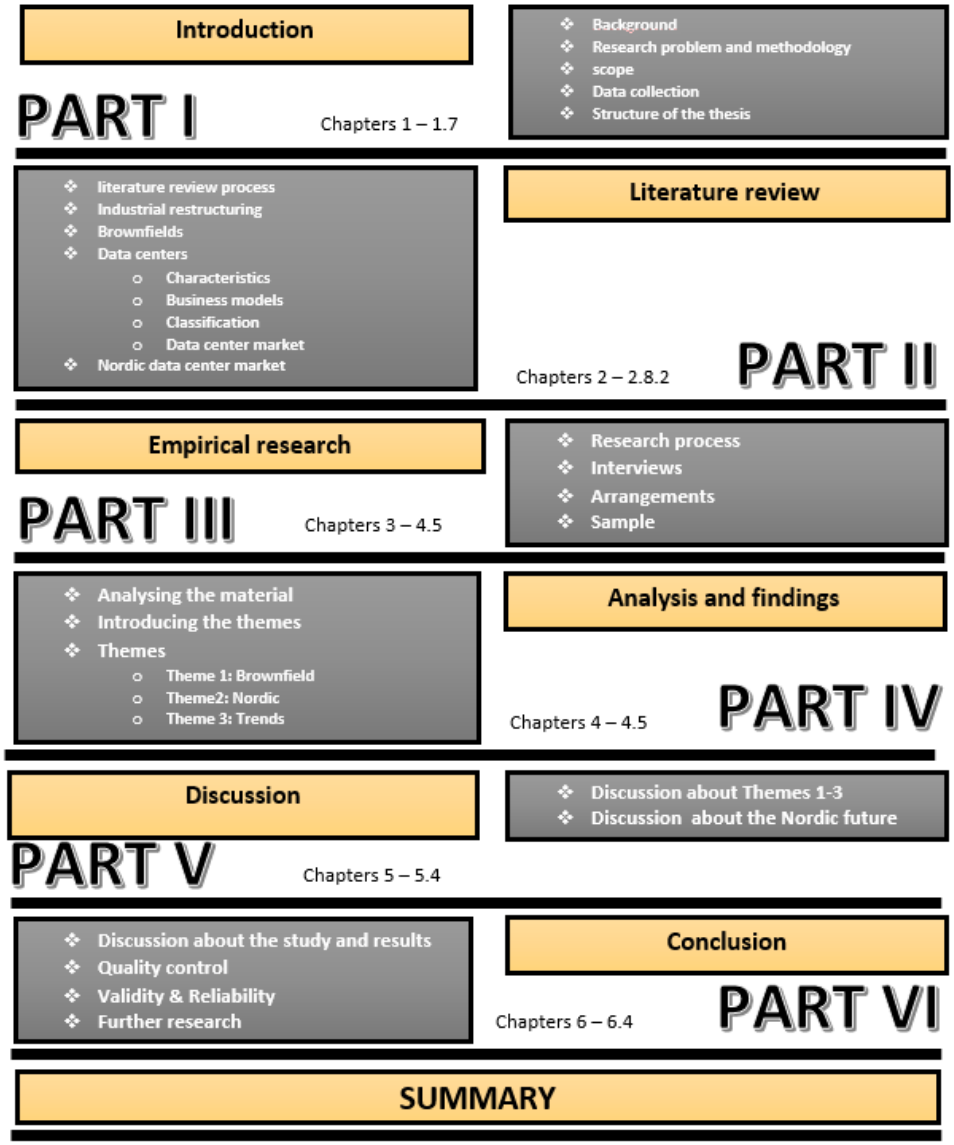

Figure 2: The general structure of the thesis

The third part (part III) of the thesis introduces the basis for the empirical research. It presents the research process and delivers general information about the interviews. Part III answers for the following questions: How interviews were conducted?, why thematic interviews were used as main data collection method? And what kind of interview sample was used in the research?

The fourth part (part IV) of the thesis consist of the findings of the thematic interviews. Each of the three main themes of the thesis are discussed separately and the key findings of each theme are introduced. In the end of each theme the key findings of the theme are presented with the illustrative table or figure.

The fifth part (part V) of the thesis is discussion. Discussion tries to rise up ideas that pop up in the interviews and compare the findings of the thesis for the existing academic literature. Researcher gives also some of his own ideas about the research itself and the key findings of the study. Discussion sets also some guidelines for different actors of the data center industry based on the general findings.

The last part (part VI) of the study presents the conclusion of the study. Conclusion puts together all the parts of the thesis and discusses if the aims of the research were achieved. Moreover conclusion presents some problems with the study and creates solutions how those missteps could have been avoided. Nevertheless, most of the problems occurred were already known before beginning the research and conclusion mainly highlight that the preliminary work was done properly. In the end of the conclusion part the reliability and the validity of the thesis are discussed and some ideas for the further research given.

2 Literature review

In this section (part II) of the thesis the concept of industrial restructuring is introduced. Finland is used as an example country to present what kind of structural changes country has experienced in the past decades[6]. Structural changes are analyzed also from the viewpoint of forest industry. That type of viewpoint was chosen since forest industry is one of the industries which has been experiencing significant structural change in the recent years.[7]

Since structural change has been rapid in certain industries it has created a large number of empty industrial sites (brownfields) in the industry regions when the previous operations have ended or moved to other regions. Even there is a possibility that the current owner needs those premises for its own business later in the future, not often this kind of development is in anyhow probable due to changed business circumstances.

Due to described reasons there is a growing need to harness those industrial sites (brownfields) being currently empty or having a closing decision for new purposes. It is important not only for the owner but often for the whole region to maintain some of the workplaces and keep the region vibrant. Existing infrastructure in the properties is often useful and can support many new functions with very little need for modifications. That is why it is essential not to let those facilities or sites to be ruined and actively search for new uses and users. Data centers are one of those possibilities that can be considered while thinking of the future use. In this thesis, data center operators are seen as potential future users of those sites and brownfield sites are analyzed in that context.

In addition to introduce the industrial restructuring and the emergence of brownfield sites, the literature review gives the reader a basic understanding about the concept of data centers and data centers basic characteristics. The general technology of data centers is presented together with the different data centers business models and the need for data centers. Literature review also presents the general criteria used in the data centers' site selection as well as introduces the global data center market. Brownfield sites are also analyzed as potential locations for data centers.

In the last headers of this section Nordic data center market is analyzed by introducing one of the Nordic countries, Finland. The data center cluster in Finland is introduced and the country is analyzed from the viewpoint of data center operators. Some of the current and future project are also introduced by delivering basic information about those projects. In

[6] One should note that structural changes vary between countries and are not necessarily happening at the same time.

[7] Another reason for the viewpoint is that this research was conducted in a co-operation with Finnish-Swedish Forestry Company Stora Enso so it was natural to analyze the structural changes from their perspective.

the very end of this section two large scale Nordic data center examples are introduced. Those two investments are the biggest data center investments in Nordic countries so far and they are used to give the reader a general understanding what kind of projects future data center investments could be.

2.1 Frame of reference

The concept of industrial restructuring is not key concepts in this thesis but it gives the reader deeper understanding why there is a great number of empty brownfield sites and why it is important to harness them for the new purposes in the future. There has been a great interest toward different economic phenomenon over time and many theorist have explained the structure of the economy by different ways. Restructuring is one of the key elements in the economics and phenomena has been explained in many ways. Recently there has been a great interest toward the restructuring process after the acceleration of globalization development and latest financial crisis.

In Finland, restructuring in the industry has been widely discussed in the recent years which has also led to some academic research. Especially big the interest has been among many institutions and organizations which have made quite significant amount of reports about the latest restructuring development in Finland.

Data centers are a somewhat different case. Academic research about data centers is mainly concentrating on the technical aspects and there is large amount of such academic research. Interesting concepts have been the energy consumption of data centers, data centers' different network structures and the cooling of data centers just to name a few topics of the recent academic studies. Those issues are surely important for the data center operators and all those quarters developing new technical solutions for data centers. In this thesis the understanding about technology behind data centers was important but the scope of this thesis was elsewhere. Interesting themes within the framework of this study are especially: The future trends of the data center industry, data center possibilities in Nordic countries and the use of brownfields in the data center context. Those themes have gained very little amount of academic research even the interest toward those themes has been growing recently at least in the media.

Lack of academic research does not mean lack of interest toward the thesis themes. Actually many international industry magazines and newspapers are targeting big interest toward data center investments in different regions (see e.g. Bloomberg 2015 and BBC News 2015). Those articles are giving the practical knowledge of the data center investments and the data center industry worldwide. On the other hand, information from the media is often limited and shows only the results of complicated decision making without going deeper into the topic. However, there are also Internet sources like Data Center Knowledge which are giving reliable up-to-date information about the data center industry (see Data Center Knowledge 2016).

2.2 Literature review process

The scope of the literature review was to construct a strong basis for the empirical research. The researcher was familiar with the concepts of structural restructuring and data centers before the thesis process but the deeper understanding was missing. The main information channels in this thesis were Aalto University Library and academic databases like ProQuest

and IEEE. Valuable information was found also from Google Scholar and other Internet sources. Also, other academic databases were used if the access was confirmed with Aalto University account. Most of the searches were conducted by using simple sentences or words which included word pair "data center". In many cases the amount of articles found was very big and search strings had to be re-formed to find more detailed information.

On the other hand "snowball effect" worked quite well in many cases. New references where found just by finding one interesting article which led to other similar articles. Webster & Watson (2002) call this method of searching for articles as a *backward or a forward method. The backward method* means reviewing the citations of the articles found in the first phase. *The forward method* means searching articles which refer to the original article.

Because the technology is developing fast it was important to use the information which was valid. Articles used in the thesis were chosen by taking into account the rapid technology development and the fact that even some of the relatively new articles can already be outdated. There was no age limit for the used articles but the goal was to use as fresh sources as possible. The goal was also to confirm the used information from the other sources (at least two other sources) if it was possible. Confirming the validity was especially important with the old articles and with the content where the technology development was considered being extremely fast (e.g. in the cooling of data centers).

A very good and relevant source of information was the master's thesis of Antti Savolainen (2013). Savolainen (2013) has done his research by considering relatively similar problems issued in this research (see Chapter 1.5). His thesis was a great source of information and gave many valuable articles through *the backward method* for the literature review.

2.3 Industrial restructuring

First of all it is essential to understand that (industrial) restructuring should not be considered as a bad thing and it is actually inevitable in the developing world and for our economy development. Alatalo and Tuomaala (2008a p. 3) explain that in the public conversation restructuring frequently gets a negative tone because in the short run restructuring development often means the layoffs of people and problems for the individuals and cities. However, restructuring is in fact almost without an exception a step forward and a path toward more productive work. Jorgenson and Timmer (2009) say that in the growth theories (see e.g. Yakova 2004 p. 69-81) economic growth is explained with the different factors such as increased labor supply, improvements in the labor quality (meaning e.g. better education), grown in capital and the technology development. All those factors bringing economic growth are also causing restructuring: For example technology development and labor quality improvements have enabled us to reallocate our resources first from the agriculture toward the industrial work and later given us possibility to change our work and society toward the services (post-industrial societies).

Honkatukia et al. (2014 p. 2) explain in their white paper, that at the same time, when we have lost some of the industrial work, new work has been created to other sectors and especially to the service sector. Yakova (2004 p. 77) tells that this development is similar to what for example economists Fisher (in 1939) and Clark (in 1940) discussed in their theories. They stated that economies are always going through different stages of production and income levels: primary, secondary and tertiary (see Yakova 2004 p. 77-78). Timmer et al. (2010 p. 30) describe that the shift toward more service orientated work has been significant

both in the U.S. and major European countries: Between the year 1980 and 2005 the share of the manufacturing labor input declined typically by one third or more and the shift has been similar also in the other goods-producing industries such as mining and agriculture.

Honkatukia et al. (2014 p. 2) describe that those jobs which were lost in one place are now reallocated to some other location or they are no more existing – client needs have changed or the technology development has made some type of work useless and there are no more need for those job functions. Some of the tasks in the industry are changing toward more service oriented at the same time when some of the old performing and routine work is relocated or done with robots or other mechanical devices. Schumpeter (2003 p. 84) might describe previous actions as an outcome of *creative destruction*. Böckerman (2011) explains that creative destruction was for Schumpeter a driving force which kept the (capitalist) economy on the move and ensured development. Schumpeter thought that (capitalist) economy is never in the equilibrium and the economy dynamics are constantly changing the structure of the economy in a kind of evolutionary process where the old structure of the economy is destroyed making space for new, better one.

Innovations were also key elements of Schumpeter's theories. Schumpeter (1939 p 98-99) believed that innovations are important drivers of economic development and lie also behind the economic fluctuation by building-up at certain times and then causing rapid development steps (i.e. in the case of a steam engine it affected immediately many industries and accelerated economic growth). According to (Yakova (2004 p. 72), in the neoclassical growth theories GDP growth is usually explained by the increased use of labor and capital but also by improving our production by technology development. If we take a look at the situation in Finland and most of the other western countries the production was growing throughout the years until the latest financial crisis (2007-2009)[8] when it dropped rapidly (see Figure 3).

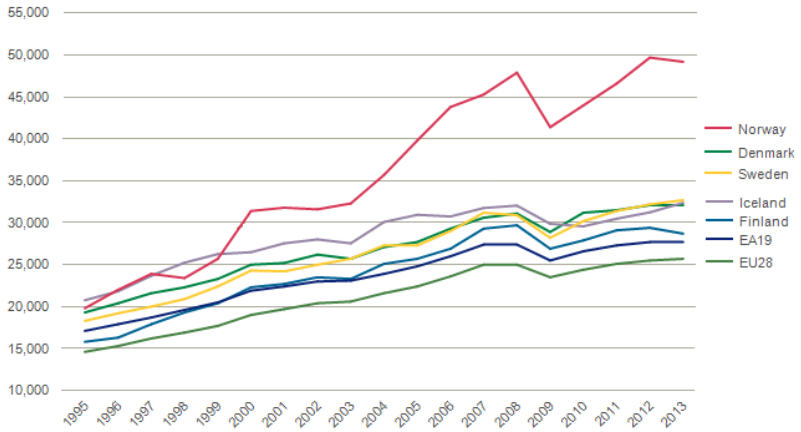

Figure 3: GDP growth per person in Nordic countries between 1995 and 2013. Note that different price levels in the countries have been taken into account and GDP values are given in Purchasing Power Standards (PPS). (Picture is modified and Åland has been removed from the original graph). (Norden 2016).

The rapid drop in the GDP of Finland is easily recognized from Figure 4. The Figure illustrates well the significant impact of the international financial crisis for the Finnish GDP development: when the annual growth of Finnish GDP was 5.2 percent in 2007 it had dropped to minus 8.3 percent in 2009 (Statistics Finland 2016).

[8] In Europe the recession started in 2008.

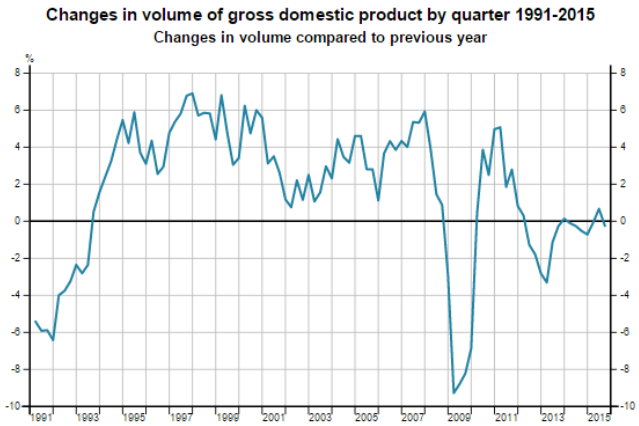

Figure 4: The GDP growth in Finland between 1991 and 2015 (Findicator 2016a).

In the following years from recession the economic growth in Finland has been mainly caused by the technology development (Figure 5). Honkatukia et al. (2014) say that the technology development will be the way of increasing the GDP also in the years to follow.

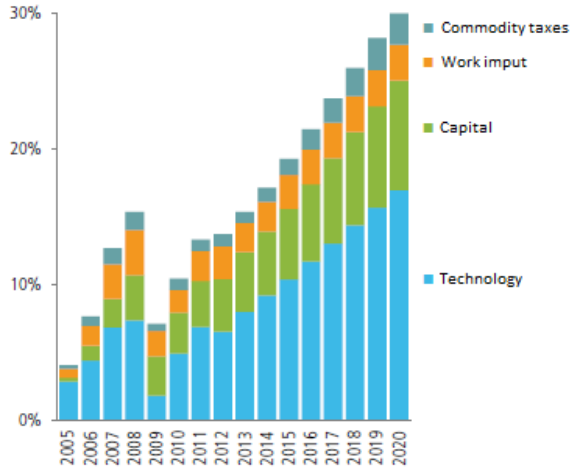

Figure 5: The contribution of supply factors between the years 2004-2020 in cumulative annual changes (%). Note that years from 2014- are estimations. (Honkatukia et al. 2014)

Alatalo and Tuomaala (2008b p. 84) explain that restructuring is a continuous process taking place all the time: the speed of the restructuring varies much and when the process is very rapid in some region it is more likely to cause problems especially if the region is not prepared to face the change. Remsu (2015) speaks about *positive* and *negative restructuring.* Positive restructuring brings new work and companies to the region when negative restructuring has opposite effects. Even the positive restructuring happens all the time, negative restructuring often gets more attention in the media. This is obvious because in the negative restructuring changes are often rapid and many workplaces can disappear overnight.[9] On the other hand negative restructuring can bring new possibilities for the economic growth when the prevailing business structure is forced to change by innovating and creating new like Schumpeter (1939) described.

[9] Companies also recruit new people constantly but shutting down a factory can mean layoffs for hundreds of workers at once.

There are, however, some risk factors which can indicate that the region is in a risk to face problems in case of a structural change. Those factors are for example: very biased or risky production structure (only one big employee), low productivity (compared with other regions), weak competitiveness and poor location (not enough educated people, bad economic circumstances in the area etc.) (Alatalo and Tuomaala 2008a p. 8; Hytönen et al. 2011 p. 41.) Especially biased production structure often leads to massive difficulties in the region if the main employee or industry faces problems. Described circumstances can be seen in the certain regions of Finland where consequences of restructuring have been extremely serious (see Alatalo and Tuomaala 2008a; Remsu 2015 p. 54.)

Alatalo and Tuomaala (2008a p. 8-9, 16) explain that some of the regions experience structural change with different ways. The size and the variety (meaning mainly education and the average age the workforce) of the labor market is different in the different regions which makes it hard to estimate how big challenges will be faced for example in the case of big layouts. On the other hand same changes can be experienced in the different way in the different regions which makes it difficult to estimate what the consequences of a structural change are in a certain region. Being able to specify which region is going to face structural change can be also difficult. Despite there would be some risk factors in an area, it does not mean that the region necessarily faces the structural change. Identifying structural change is also little complicated: restructuring happens all the time so when one region is defined to be facing structural change it often means that the structural change is only more rapid than how it would be in the normal circumstances.

2.3.1 Industrial restructuring in Finland

In this thesis industrial restructuring is described by using Finland as an example country among Nordic countries. Structural changes have not been exactly the same in all the Nordic countries and some of the restructurings have happened in the different time due to different history of the countries. Still, it is important to note that some of the phenomena which have caused structural change in Finland are international (e.g. the invention of a microprocessor, globalization development and climate change) and are more likely to affect countries worldwide causing structural change.

The latest major industrial restructuring (structural change) in Finland has begun quite the same time with the international financial crisis and weak international economy development. Also some new megatrends (e.g. digitalization) and changes in the customers' behavior (in example the growth of the internet shopping) have been influencing the change and the latest restructuring development (Työ- ja elinkeinoministeriö 2015a p. 19, 38, 45). Especially digitalization has decreased the use of paper products which has been very negative development for Finnish forest industry (Hetemäki and Hänninen 2009; Hetemäki 2006). Restructuring has hit some of the regions in Finland very hard and they have faced major challenges when companies have reorganized their operations causing large scale layoffs (see Ylikännö and Kehusmaa 2015). Alatalo and Tuomaala (2008a p. 33; 2008b p. 89) say in their both articles that similar restructuring development is more likely to continue in the future: Some of the operations are still being reorganized and enhanced, globalization development will take place and clients need vary in time, all of them causing restructuring pressure for companies.

Current restructuring development is not any unique phenomenon in Finland and big restructurings have been seen before. Finland is a small and export oriented country so it is

sensitive to the changes in the international economy. Kuusi (2013 p. 11-13) writes that significant restructuring took place in Finland also at the beginning of 1990. Back then Finland faced a serious economic depression said to be one of the worsts in the industrial countries and the most serious one in the history of OECD. (Timonen 2003 p. 4; Kuusi 2013 p. 11). Kuusi (2013 p. 11-13) writes that researchers are not entirely anonymous about the reasons for the crisis. Anyway few different phenomena can be found: Financial liberalization had just taken place in Finland and caused serious problems especially in the banking sector. The collapse of the Soviet Union at the beginning of 1990 hit Finnish exports very hard and combined with other problems (e.g. decrease in the production and investments) in the Finnish economy played a big role in the crisis.

In addition to those two recent restructuring waves there have been several other structural changes in the history of Finland. Here below is listed what were (the trends) and structural changes in different decades. The list is based mainly on the Kari Hietala's (1994 p. 18) list of the structural changes in Finland (decades from 1960 to 1990). Last two decades are based on Alatalo and Tuomaala (2008a p. 2).

1960s: **Moving into cities:** Big change in the economic structure of Finland. People begun to move from the countryside toward the cities. Industrial and service work begun replacing primary production.

1970s: **Relocating the work and labor:** The economic structure was still in a big reform and some of the production was relocated to the countries with the lower labor costs.

1980s: **Innovations create new work:** New innovation processes: Release of a microprocessor/computer, development in the microelectronics and better data processing brought many possibilities but also challenges.

1990s: **Joining EU:** Finland joined the EU which opened the market but brought also more competition and competitors to domestic market. More possibilities for the trade but also some pressure for the companies to answer the challenges of more open competition.

2000s: **Globalization:** Globalization development affected considerably on certain industries in Finland. Restructuring was necessity for the companies to face the new challenges. The second phase of globalization brought competition on company level.

2010s: **Climate change:** Answering the climate change development. Changes in the energy use, costs and production. [10]

[10] Here should be noted that above list is more or less subjective perspective of what have been the structural changes in last centuries in Finland. For example many people could name Finnish economic depression as a force of restructuring in 1990s as well as international financial crisis in the end of 2000s.

As mentioned before, structural change is a continuous process which happens all the time in its different forms. Alatalo and Tuomaala (2008a p. 2) say that the structural changes that have been typical for the different centuries in Finland are not yet completely over and the same kind of development still occurs. The service sector for example keeps growing and the ever greater proportion of people are moving into cities (both phenomenon starting in the 1960s). Manufacturing work is also still disappearing from Finland even the development started already in the 1970s. Alsen et al. (2013) expects in their report "Revitalizing Nordic Manufacturing" that Finland will lose about 42 000 workers from the manufacturing by the year 2020. This means 11 percent of the manufacturing workforce from the level of the report in 2013. According to the report, sectors expected to suffer the most from the restructuring in the future are electronics, chemical industry and paper industry.

We can actually say that none of the Hietala's (1994) restructuring trends of different decades have yet completely disappeared even the forms of restructurings might have slightly changed. The speed of the development has even accelerated in some of the areas and adoption of new things and ideas has become a necessity (i.e. adopting new ICT technologies is very essential to many industries). Alatalo and Tuomaala (2008a p. 3) explain that in the recent debate one of the biggest themes has been globalization (see Valtioneuvoston kanslia 2006). Kahilainen (2000 p. 8 - 10) describes that globalization is, however, not a new thing. Nevertheless, the speed and the way how it affects the whole world is different from the past, especially due to rapid development of information technology, which enables the rapid flow of information. Globalization has been especially important for the economy development and to different companies enabling them to spread their business and conquer new markets.

Baldwin (2008 p. 9 - 34) says that we can see two major phases in the globalization development: in the first phase low-skilled and manufacturing work is offshored from the developed countries to the lower cost countries – idea is to focus on lowering the unit costs of trading goods. This kind of development has realized not only in Finland but in many developed countries. In the second phase of the globalization the competition is no more restricted only in the certain industries and it consists of a large variety of different companies but also different work tasks.

Baldwin (2008 p. 23) describes that in the second phase of globalization, global competition arrived at the company level. Those tasks that used to be so called non-traded, became also traded. The main motor for this development was the huge drop of the telecommunication costs which enabled the described development. One commonly used example of this globalization phase is the moving of call centers from the U.S. to India.

Both described phases of the globalization are more likely to be seen side by side in the future. Alatalo and Tuomaala (2008a p. 13) describe that maybe in that context the fact that Finland has more industrial production compared with many other Western countries is a bit worrying – some of that production can still be transferred abroad. On the other hand Ali-Yrkkö (2006) mentions that digitalization and better telecommunication is making possible that production but also some of the services can be produced in the other location than where they are used. This development does not necessarily have to happen outside the country and can and happens also inside the countries. Described development is not just a threat to Finland and should be seen as an opportunity: Finland as well as other Nordic

countries can concentrate on industries and goods where they have advantages among the others and try to lure those industries (e.g. data centers) to the countries.

The production structure of the companies is also changing. Ali-Yrkkö (2006) says that many big industrial companies are no more interested in the manufacturing process. This means that the real manufacturing is done by partners or subcontractors. Big players want to specialize only in certain parts of the production chain instead of taking care of the whole production process. This means that companies might only want to take part of the designing, marketing and maybe the final assembling process but to give all the other parts of the production chain to other subcontractors. Also, the development of new products can be done in a cooperation with other companies or some parts of development process can be bought from other organizations.

In Finland the aftermath of financial crisis has been driving forces of the structural change in the beginning of the 2010s. The prolonged economic downturn in the Finnish economy has caused major difficulties to many companies and the whole country. Vuorensola (2015 p. 11-14) says that hard economic situation has forced many companies to make major structural changes: many factories have been closed and services have been relocated. Also, the unemployment rate has climbed high and was this February 9.4 percentage. If we compare that value to the unemployment rate prior to the financial crisis, there is a rise of about 3.5 percentage points (Tilastokeskus 2015; Findicator 2016b.) Downward in the economy is nevertheless not the only reason for the structural change in Finland. After the latest financial crisis international competition has increased and Finnish companies have not succeeded in the international competition as well as before (Eduskunta 2015; Elinkeinoelämän keskusliitto EK 2013). Vuorensola (2015 p. 7, 18-19) writes that this has forced companies to reorganize their function to answer better for the new competition challenges in the international competition.

Alatalo and Tuomaala (2008a p. 3) expected in 2008 the big trends of the 2010s will be climate change and energy issues. In fact those themes have been rising their importance during the first half of the 2010s and climate conference in Paris and Paris agreement (see United Nations 2015) showed the whole world that the concern about the climate change is a common problem and there is an international intention to mitigate it (Ministry of the Environment 2015a). Halme et al. (2014) rose the conversation about Finland's energy policy in the limelight at the beginning of 2014. She and the group of professors proposed Finland to make a turn in its current energy policy and get rid of the big share of the exported energy and start supporting renewable energy sources. This turn has already been done among many countries in Europe (in the report example countries representing positive energy policy were Sweden, Denmark, Austria and Germany).The main question in Finland is, if it relies on its current energy mix (consists of a large share of imported energy and own production relies on nuclear power as a primary solution) in the future. Still, big decisions about the future energy strategy are yet to be done and restructuring has not yet completely started in the energy sector.

Industrial restructuring can be a painful process: especially industrialized subregions can face problems when big employers reduce a lot of the employees at once. Running down the factories or other changes in the production can hit the regions hard and recovering can be difficult and painful (Työ- ja Elinkeinoministeriö 2016a). Restructuring development can happen very rapidly and many jobs can be lost even overnight. Restructuring is not a

marginal phenomenon. According to European Commission's (2009 p. 6) "Restructuring in Europe 2008" report, between 2002 and 2007 more than 7 000 cases of large-scale restructuring were recorded in the EU member states. Yet those large-scale restructurings are only showing one truth and so called *"silent restructuring*" is constantly happening in the smaller scale.

As mentioned, restructuring processes can be painful for the single employees, companies, industries or regions. EU can ease those processes with its financial instruments *European Social Fund (ESF)* and *Regional Development Fund* by giving support for example old industries to modernize production structure or methods (European Commission 2009 p. 9-13; 119-132). Vuorensola (2015 p. 22) describes that the Finland Council of State has named restructuring areas or industries as ÄRM regions or industries since 2007 (see Vehkasalo and Pottonen 2012). This status has been given to the regions or industries where restructuring process has been extremely fast. Regions or industries have got ÄRM status for three years at once. During those years, government has targeted extra funding for the region or the industry from its investment or other development funds to support infra investments or re-education in the region. In Finland, there were 14 ÄRM areas in 2015 (situation 16th May 2015) (Työ- ja Elinkeinoministeriö 2016a).

2.3.2 Industrial restructuring in the (Finnish) forest industry

Finland has been said to stand in its wooden legs meaning that the country has lived for its forests and wood product. This proposition has been more or less true until the restructuring development hit also the forest industry in Finland and the industry was forced to run down the production and factories.

The latest restructuring in Finland has been significant in the forest industry. In Finland ICT sector and the forest industry together with other traditional industries have been facing the most significant restructuring in the recent years (Työ- ja Elinkeinoministeriö 2016a). In this thesis restructuring was examined from the viewpoint of forest industry since restructuring has freed many industrial sites among the industry in Finland and other Nordic countries.[11]

The forest industry means both mechanical and chemical industries. In this thesis restructuring in the forest industry concentrates especially on chemical forest industry meaning pulp and paper production. Particularly chemical forest industry has been facing a hard period of restructuring when the demand for the paper products has been decreasing and the capacity has been too big in comparison with the demand (Häyrinen 2011 p. 21). Rytteri (2010 p. 3-4) tells that restructuring has meant closures of paper mills and redundancies of workers among the industry. In some regions, those actions have caused big economic effects and meant significant problems.

Rytteri (2010 p. 3) writes that between the year 2005 and 2010 the total capacity of paper and cardboard production decreased by more than 20 percent in Finland. When forest industry consisted 29.3 percent of the Finnish exports in 1998, 2008 its share had decreased to 17.4 percent. During those ten years, forest industry in Finland lost more than 15 000 workplaces (Hetemäki and Hänninen 2009 p. 2). In 2010, Rytteri (2010 p. 3-4) estimated that the development is not yet over and restructuring in forest industry will bring more rundowns of paper mills in Finland. Rytteri (2010 p. 4) argues that for example the future

[11] Forest industry was chosen also because of the interest group of the thesis. In principal industrial restructuring could have been analyzed as well from the viewpoint of some other industries.

strategies of Finnish leading forestry companies Stora Enso and UPM concentrate on the new developing markets in Asia, South Africa and Russia. Demand for the paper and pulp in Europe is decreasing but at the same time increasing in the developing countries. By considering that, relocating production closer to the end users is probable development. Besides, the cost of the wood is significantly cheaper i.e. in Southern America because of the faster growing timber and cheaper harvesting.

Rytteri (2010 p. 4) says that restructuring of forest industry has not been faced just in Finland. The recent development has been similar in Sweden but also in the Northern America. Forest industry and paper mills have traditionally located in remote places and factories have been the biggest employees in the regions. When the restructuring has then hit the industry, regional consequences have been significant. According to Wikipedia (situation 18th Sep 2015) total of ten paper mills and four of pulp mills were closed between the year 2005 and 2015 in Finland (Wikipedia-projektin osanottajat 2016). Rytteri (2010 p. 4) names the announcement of the shutdown of Kemijärvi pulp mill in 2007 being especially hard when 223 people lost their jobs in the region where the mill was the biggest employer. Same kind of situation was experienced two years later in Quebec, Canada when Pine Falls newsprint mill shut down its production and 270 people lost their jobs.

At the moment, the restructuring in the whole forest industry is very significant and we are unable to find very much comparison from the history. List below is based on Hetemäki et al. (2011 p. 14) list of several trends behind the current restructuring development in the forestry.

1. **Globalization**
2. **Digitalization**
3. **Concentrating on fast-growing plantation forests**
4. **Climate change and environmental regulations**
5. **Energy issues**
6. **Developing countries turning into post-industrial societies**

Hetemäki et al. (2011 p. 14) say that there have been also other changes affecting the structural change such as the e.g. *"change in the values of forests and their use"*. Hetemäki et al. (2011 p. 14) are also predicting more hard times for the forest industry. Those visions are very similar to the thoughts of Rytteri (2010) described earlier. Hetemäki et. al (2011 p. 14) thinks that the process in the forest industry is now similar to the Schumpeter's concept of creative destruction and new production will gradually displace the old model (concept of creative destruction was introduced in the Chapter 2.3).

On the other hand restructuring is not a new thing in the forestry and restructuring processes have been shaping the sector through its existence. Hetemäki et al. (2011) take a closer look at the history and development of forest industry in Finland and make a clear picture that there have been big changes in the production structure also before.

In Finland forest industry has its roots in the 16th century when first hydro-powered sawmills started operating. Till the mid-1800 Finland was partly the biggest tar exporter in the world which gave important capital for opening the first stem sawmills in the 1860s. The true kick

for the Finnish forest industry was the inventions which made possible to produce paper from the wood fiber in the mid-1800s.[12]

Hetemäki et al. (2011 p. 22) write that growing forest industry meant unprecedented growth in the demand for wood. Demand growth meant positive price development and the value of forest and timber grow to new levels. Development of the saw and paper industries begun the industrial revolution in Finland. The next "revolution" in the Finnish forestry was seen after the Second World War: forests were harnessed for the economy needs and industry turned into intensive forestry. Intensive forestry meant for example peatland drainages, extensive clearcuttings, constructing of forest roads and fertilizing of forests together with other methods boosting the use of forests.

In the 1970s forest industry in Finland faced profitability crisis. Profitability crisis forced forest industry to change its degree of processing and concentrate on highly processed products like printing and writing papers. More competitive markets in the 1980s meant problems for small operators (companies) when the need for big investments grew. This development led to more centralizing and the amount of companies decreased dramatically. When coming to the 1990s companies had to answer for the globalization development and after the year 1998 Finnish forest industry has made more investments abroad than domestic (Hetemäki et al. 2011 p. 25.)

Until the beginning of the 2000s Finnish forest industry seemed to be doing well and profitability was moderate. Then the demand for the forestry products started to fall in the main markets. Reacting for the trend was slow in the Finnish forest industry and investment kept growing despite the downward trend. Since devaluating the Finnish own currency (mark) was no more possible (the euro has been in use since 2002) for easing the falling demand and growing production costs, industry slid into profitability crisis. This crisis has led to the restructuring processes in the whole industry and current development (Hetemäki et al. 2011 p. 25.)

Hetemäki (2009 p. 455) estimated 2009 that the forestry in Finland was in a phase where mainly negative effects of the *creative destruction* were visible and there was very little positive development in the industry. Hetemäki estimated that in the future the growth in the industry has to be found somewhere else than in the past. He mentioned biofuels, wood based energy production and chemical industry products being possible future growth factors. However, he said that when considering the restructuring development in the forest industry should be noticed that the restructuring and "destruction" have been significant only in the paper industry – packaging or wood product industries have not been facing same kind of change.

The structural change in the Finnish forest industry can be seen clearly for example in the turnover of Stora Enso. When paper business covered in 2006 almost two thirds of the company's turnover its share in 2014 was no more than somewhat over one third. Also the future strategy of the company concentrates more on biomaterials, cardboards, packaging solutions and wood construction instead of paper production (Stora Enso Oyj 2014.) The development of another Finnish forestry company UPM has been very similar to Stora Enso and the share of paper production is decreasing (was still almost 60 percent of the turnover

[12] Before mid-1800s paper was produced from the rags and strokes (Hetemäki et al. 2011 p. 21).

in 2014 but has decreased significantly since 2003). In the future UPM concentrates more on new businesses like biorefining, energy and pressure sensitive labeling solutions. From the old businesses UPM estimates the pulp production growing in the future (UPM 2015; UPM 2014.)

It seems that both companies have found new growth paths after restructuring development in the industry. The future growth will be based on the new businesses which were in the background before the restructuring hit the industry and changed the production structure. Maybe the restructuring in the industry is not yet completely over but it seems that the production structure has already changed significantly.

2.4 Old industrial sites (in Finland)

In this thesis old industrial sites are considered of being sites that have been past in the industrial use. Those sites often locate in the urban structure and because of the global restructuring in some of the traditional industries (e.g. steel and textile industries) the use of those sites has decreased or ended. Restructuring has happened also in the city structure and some old city functions like harbors or railway yards have moved to other places (Ramboll 2015 p. 3; Grimski and Ferber 2001 p. 143-144.) Economic restructuring has decreased the amount of industrial activities in the developed countries and more work has been created to the service sector. This has resulted as abandoned industrial sites particularly in the urban areas (Grimski and Ferber 2001 p. 143-144). In Finland restructuring has been significant in the traditional industries (forest and metal) but also in ICT sector so it is obvious that industrial sites in Finland have usually background in those activities. (Työ- ja Elinkeinoministeriö 2016a; Honkatukia et al. 2014).

The purpose why this thesis targets big interest toward restructuring is the fact that many old industry properties are currently empty or only partly used after the structural change in the industry. According to Grimski and Ferber (2001 p. 143) there is a need to get those sites to the real estate market again and create them new economic use. In this process environmental restoration, new land-use planning and economic policy have to be taken care to ensure their proper use in the future.

One might say that it is also important not to let those sites and theirs infrastructure to decay since existing infrastructure can be useful for many types of purposes. Even the actual buildings would no more be utilized, other infrastructure meaning roads, pipelines, the electricity network etc. can still be useful for the new owner. Grimski and Ferber (2001 p. 143) write that restoring those sites also improves the environment and can attract new investments for jobs, housing and public facilities. Reusing and redeveloping those old industrial sites can also ease to meet the targets of integrated and sustainable land use.

Old industrial sites are often called with commonly used term *brownfields* which refers to their previous use in industrial purposes (e.g. factories). Brownfield as a term can, however, refer also for other previous uses such as railroads, harbor infrastructure or other commercial uses (Grimski and Ferber, 2001 p. 144.) Still, in this thesis term refers especially to the previous industrial use.

Brownfields have some advantages compared with unbuilt *greenfield* sites such as existing infrastructure[13] and often excellent location – so there should be growing interest towards them (Ramboll 2015 p. 4-5). Brownfield development can also increase the value of the surrounding real estates significantly (see Ramboll 2015 p. 5-6). Brownfield sites can be harnessed for the similar purposes like they were used in the past or completely different way.

2.4.1 Brownfields

Term *brownfield* is often used when speaking about old decayed industry buildings, warehouses, traffic areas and contaminated or other way ruined sites (Niitemaa 2003). Still, the definition of brownfield differs widely between countries (Paccagnan and Turvani 2007 p. 2).The term has its origin in the U.S. where it is commonly used. The use of a term has since spread to other countries and been adopted to use in the other industrialized countries too (Vanheusden 2007 p. 569). Especially in the U.S. brownfields refer to contaminated sites. United States Environmental Protection Agency (2015a) describes brownfields as following way:

Brownfields:
""Brownfield site" means real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant."

Siebielec et al. (2012 p. 3) describe that there are no specific regulations in the EU for brownfields. CABERNET (Concerted Action on Brownfield and Economic Regeneration Network) is a European organization dealing with different brownfield regeneration processes. They define brownfield sites as follows:

Brownfield is a site which:

- *Have been affected by former uses of the site or surrounding land*
- *Are derelict or underused*
- *Are mainly in fully or partly developed urban areas*
- *Require intervention to bring them back to beneficial use*
- *May have real or perceived contamination problems (Cabernet internet 2015)*

Siebielec et al (2012 p. 3-5) discuss that this definition is similar to how different European countries define the term. On the other hand there is yet no official definition for brownfields at the EU level and countries have different versions of defining the term. Lack of the common definition is, however, a little strange since the problem has been acknowledged already long time, and CABERNET was highlighting its importance already in 2004 in the report "the Scale and Nature of European Brownfields"(Oliver et al. 2005). Yet the issue has been highly noticed and it appears in several regulations and development programs of member countries.

According to Vanheusden (2007 p. 561-561) the amount of brownfields is very big. Even there has been no real inventory in the EU states, the number of brownfields in the EU-27 (all the member countries in 2015 except Croatia) was estimated to be 3.5 million with 500 000 sites with the significant contamination and need for remediation. It can be

[13]Consists of roads, railways, electricity networks and water pipes etc.

estimated that the amount of brownfield sites is still relatively close to that number even some of the sites have been harnessed for the new uses and new brownfield sites have born because of the continued restructuring development. However, the exact number in the EU is still hard to define due to lack of common definition. Environmental protection Agency (EPA) estimates that there are more than 450 000 brownfields in the U.S. (United States Environmental protection Agency 2015b)

Siebielec et al. (2012 p. 8) state that the problem with the brownfields, in addition to the lack of common definition, has been the lack of credible information in the spatial format. This has been a problem why many countries (in Europe) have not been able to make a clear and effective program for redeveloping their existing brownfields. When speaking about brownfields, the existence of environmental problems has to be always considered. Since the definition of brownfields is broader in Europe than in the U.S., not all the brownfields are contaminated. In many cases contamination may be only partial or relatively low. Siebielec et al. (2012 p. 12) say that for example when a study of industrial brownfields in Austria was conducted, about 85 percent of the sites had no contamination or the contamination was only little.

Brownfields have been transformed into various land uses. Common application has been transforming them into residential or commercial properties (e.g. industrial parks, shopping centers or offices). This is possible development when sites locate in the central locations and are solid part of the urban structure. This kind of development has taken place for example in Helsinki, where old harbor areas have been deployed into new uses (see Uutta Helsinkiä 2016a; Uutta Helsinkiä 2016b).

Even brownfields have some problems, they also have possibilities. Siebielec et al. (2012 p. 13) state that brownfields should be seen as real alternatives for the greenfields. Many of the sites classified as brownfields do not need even cleaning or the contamination is relatively small. Some of the brownfields also have excellent existing infrastructure which might even reduce the costs of investment (compared to greenfields). According to Brecheisen and Theis (2013 p. 1) many brownfield sites have potential to become economical solutions and more importantly host new businesses and create new jobs in the future. The use of brownfields as data centers is introduced in the Chapter 2.6.9.

2.4.2 Brownfield possibilities and the typical development process

Sites or environments that have past been in the industrial use but are now empty or in a minimal use are called brownfields (see some commonly used definitions in the previous Chapter). Those sites can be completely abandoned or the present use is very minimal. Danish engineering, design and consultancy company Ramboll (2015 p. 1) describe in their white paper that the current use of brownfield sites can be difficult since the harmful previous use of the sites – contamination or other various reasons (e.g. dilapidated buildings etc.). Therefore, brownfield sites need to be refitted to the purposes of new user (Glumac et al. 2013). Some of the brownfield sites also have culture historical value which can hamper the future development of those sites. Brownfield sites have also often been designed for some special purpose which makes them difficult to harness for the new uses (Ramboll 2015 p. 1.)

Reasons for the born of brownfields are linked to the social changes, restructuring in the industry or changes in the structures of the cities (Ramboll. 2015 p. 4; Grimski and Ferber 2001 p. 143). For example the rise of the land value in the cities has caused changes in the

structures of areas: i.e. industrial areas and harbors have moved away from city centers to other more cost efficient areas. Restructuring has also emptied many old industrial but also commercial buildings which have been an integral part of the urban structure in the past. Those kind of brownfield properties are for example old factories, hospitals or garrisons. By harnessing those areas or facilities again we can keep areas lively and bring them back to life (Ramboll 2015 p. 4.)

EU has been promoting the use of brownfield sites and supporting of creating the tools and methods for easing brownfield development. In the U.S., they came already in the 1990s to the result that developing brownfield sites is reasonable and enables to achieve both economic and environmental benefits (Ramboll 2015 p. 5-6; Attoh-Okine and Gibbons 2001 p. 126.)

Still, there are some problems related to brownfields. Glumac et al. (2013 p. 795-796) state that one of the problems is actually the big amount of brownfields but at the same time alternative opportunities (greenfields) to be developed. Greenfields are often simpler cases because there are no issues with the contamination, complicated landownership or other related risks. Lange et al. (2014 p. 1) say that the uncertainty of the many issues like contamination, ownership, costs for remediation and infrastructure improvements are making actors to hesitate when thinking about investing in brownfields. Both Glumac et al. (2013 p. 795-797) and Lange et al. (2014 p. 5) describe that on the other hand nowadays greenfields are more likely to locate far from the city centers which can cause fragmentation of the city structure. In addition, the supportive infrastructure for greenfields has to be built at the same time with the facility – in the brownfield environment the infrastructure is often already on site. Also, the lack of information or wrong believes about the condition of the brownfield sites can lead into misunderstandings and lack of attractiveness among the potential brownfield developers.

Koch (2006 p. 76) highlights that brownfields can compete with undeveloped urban fringe properties (greenfields) in case all the parties have the understanding about the risks and effects of the contaminated property. Koch continues that financial incentives can also drive the brownfield development by helping investors/developers with the cleanup costs. He says that there is a growing pressure toward the redevelopment of brownfield properties because of the increased costs and taxes of raw land but also due to political restrictions designed for restricting the urban sprawl. Attoh-Okine and Gibbons (2001 p. 129) have listed several reasons why brownfields should be returned to the productive use. Positive factors for brownfield redevelopment are such as:

- Revitalizing inner-city neighborhood
- Creating new jobs and tax revenues
- The protection of human health and natural resources
- The renewal and reuse of the existing civil infrastructure
- Greenfield protection (using first the empty available brownfields)
- Having control of the urban sprawl.

In addition to those positive factors brownfields can also have other positive features: They can be (often) bought with the cheap price and they tend to have central location which offers good availability of workforce and supportive services (e.g. messenger and maintenance services) for the different businesses. Still, Attoh-Okine and Gibbons (2001 p. 129) add that

despite the large amount of positive factors there are still many difficulties in the brownfield development including financial, technical and socioeconomic constraints and all types of uncertainties in site information (which have been discussed already in this Chapter). Attoh-Okine and Gibbons (2001 p. 128-129) explain that most of the brownfield redeveloping process follow the process of four steps:

1. Identification of the site
2. Assessment of the site
3. Remediation of the site
4. Redevelopment of the site

Site identification is an important process where the history and previous use of the site is identified. At first it is important to clarify if the site is contaminated and what kind of contamination it is. In the U.S a Phase I site assessment is often conducted by the environmental consultants during the site identification.[14] Phase I assessment provides an analysis of government and other historical records but also performs site reconnaissance studies, interviews the owner(s), occupant or other site associated actors to define the existence of contamination on site. The basic idea of conducting the Phase I assessment is to identify the need for further investigation in the site – if something has to be investigated more deeply (Bower 2016).

Assessment of the site: In case the Phase I site assessment reveals contamination on the site, Phase II assessment may be conducted. In the Phase II assessment samples or tests for the hazard(s), (possibly) identified in the Phase I may be conducted to ease the planning of the site remediation (United States Environmental Protection Agency 2006). Phase II includes the samplings of soil and groundwater which identify the type and extend of site contamination. In the Phase II assessment, the cleaning technology for the site is determined together with the estimation of the costs of the remediation process. The level of the cleaning depends on various factors such as the surrounding land use, associated risk and toxicity, economic consideration and future land use.

Site remediation involves the actual remediation for the site which will be based on the findings in the previous steps and assessment phase(s). The cleanup levels for the site will be determined by considering the cleanup standards (legislation) of the particular location and the future land use.

Redevelopment of the site: In the redevelopment of the site several issues has to be taken into consideration. Those issues include such as financial, technical, liability and socioeconomic contains, uncertainties due to inadequate site information and competing redevelopment objectives. Those issues have to be taken into consideration to achieve the new productive reuse of the brownfield site. (See Attoh-Okine and Gibbons (2001 p. 128-129)

[14] Phase I and II Environmental Site Assessments (ESA) are used especially in the U.S. Assessments are created to evaluate the environmental issues of the sites which have been previously used for commercial purposes. (see The Small Business Environmental Assistance Program 2014)

2.5 Data centers

2.6 Defining the data centers

> *"Data centers are designed for computers, not people. As a result, data centers typically have no windows and minimal circulation of fresh air". (Brown et al. 2008 p. 18)*

Data centers are often large facilities housing big amount of information technology (IT) equipment. Those equipment are used for three main functions: store, process and transmit digital information (Yogendra and Kumar 2012 p. 1). Data centers are used to provide services to the entity operating the data center or/and to external clients (Lääkkölä 2015 p. 6). Data centers consists of multiple equipment: servers/computers, switches, fibers, storage units, load balancers, power suppliers, cooling systems and communication gears (Barroso and Hölzle 2009 p. 2; Dai et al. 2014 p. 9). The IT equipment is housed in the electronic cabinets or rags which are arranged with the standardized dimensions. Power conversion and backup equipment are often included in the normal data centers configuration to maintain reliable and high quality of power supply. Environmental control equipment are also important part of the data centers equipment for maintaining the right temperature and proper humidity conditions within the facility (Yogendra and Kumar 2012 p. 1). An example of a typical data center facility is shown in Figure 6.

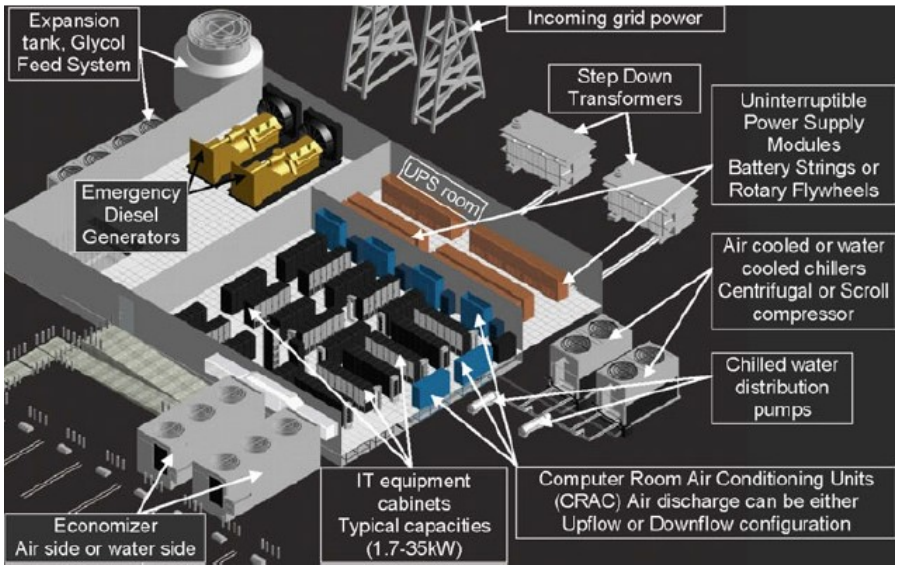

Figure 6: Typical data center facility (Note that not all the data center facilities include all the components shown in the figure) (Yogendra and Kumar 2012 p. 2).

Yogendra et al. (2012 p. 2) say that there are various users who exploit data centers. Those end users include individuals, Internet service providers, banks, stock exchanges, corporations, educational institutions, government installations and research laboratories. Barroso and Hölzle (2009 p. 2) describe data centers typically being permanent facilities focusing on the long term maintenance, the distribution of data and data products archiving. They typically host a large number of relatively small- or medium-sized applications. Those applications run with the dedicated hardware infrastructure which is de-coupled and has also the protection of the other systems in the same facility. Described characteristics are important since data centers often host hardware and software of different organizational units or even different companies. In such data centers, different computing systems have

usually not much in common in terms of the hardware, software or maintenance infrastructure and they are not communicating with each other.

Mega data centers
Mega data centers or warehouse-scale computers (WSCs) are data centers in the big scale. They are usually operated by the big Internet operators such as Google, Amazon, Yahoo, Microsoft or Facebook (Greenberg et al. 2009 p. 68). Barroso and Hölzle (2009 p. 2-3) describe that mega data centers differ from the traditional data centers in certain respects: Mega data centers or WSCs are operated by the single operator, have relatively homogenous hardware and system software platform and are sharing a common system management layer. When conventional colocation data centers run with the big variation of third party software and application (more information about different business models in chapter 2.6.2), WSCs often have lots of in-house build applications, middleware and system software. WSCs differ from the other data centers also because they often run with much smaller variation of applications (or Internet services) than conventional data centers.

One big advantage in the WSCs compared with other data centers is the resource management infrastructure. In WSCs it is common for the whole data center which is enabling significant deployment flexibility compared to other data centers. Having one operator allows the organization also to concentrate for example on the cost savings or the reliability of the service easier than in the traditional data centers since the amount of different systems is much smaller (Barroso and Hölzle, 2009 p. 3.) In the large data centers the economies in scale can be realized while the purchasing prices of the servers and other equipment are cheaper when buying large quantities (Greenberg et al. 2009 p. 68; Barroso and Hölzle, 2009 p. 4). According to Greenberg et al. (2009 p. 68), large data centers also "scale out" meaning that they can use low cost servers and hardware to share the total workload while in the smaller data centers it is not possible because they are often optimized with the physical space and number of high-price servers.

2.6.1 Characteristics of Data Centers

A data center includes various kind of equipment. Dai et al. (2014 p. 9) tell that those equipment can be categorized into four different categories first of the categories being the actual IT equipment and the other three representing the supportive infrastructure for that equipment: (Note that the configurations can vary between data centers)

1. Power equipment:	Includes power distribution units (PDUs), uninterruptible power supply systems (UPSs), switchgears, generators, power distribution units and batteries.
2. Cooling equipment:	Chillers, computer room air-conditioning units (CRACs), cooling towers and automation devices.
3. IT equipment:	Servers, network and storage nodes, supplemental equipment (keyboards, monitors, workstations and laptops used to monitor or control the data center).
4. Other miscellaneous components:	Lightning and fire protecting systems.

Power equipment:
There are both PDUs and UPSs in the data centers power equipment. UPS systems are typically combining three different functions in data centers. Functions are described according to Barroso and Hölzle (2009 p. 41) and Dai et al. (2014 p. 11).

First function is a use of a transfer switch. This switch chooses the active power input which can be either utility power or generator power. In case of a power failure, switch senses if the generator (in a big data center can be many) has started and is ready for providing power for the data center. If the generator is operational (it is typically taking about 10-15 second to start and be ready to provide power), then it is switched to become the active power system for the data center (Barroso and Hölzle 2009 p. 41; Dai et. al. 2014 p. 11.)

Second function is the use of batteries or flywheels. The function for those is to bridge time between the power failure and the availability of generator power. Thus, this design secures that in case of a power failure the internal DC power of the UPS system is retained until it is possible to use the power supply of the generator. In the typical UPS, this is done with the AC-DC-AC double conversion which means that the input AC power is converted to DC which then feeds the UPS-internal DC bus that is also connected to the strings of batteries. To feed the data center equipment the output of DC bus has to be converted back to AC again. Thus, in case of a power failure, the UPS loses its input AC power but retains the internal DC power. Internal DC power is retained since the batteries still supply it and the AC output power is still available after the second conversion step. Then eventually when the generator is operational and starts supplying input AC power the UPS batteries are freed for the data center load (Barroso and Hozle 2009 p. 41; Dai et. al. 2014 p. 11.)

The third function of UPS is to condition the incoming power feed. This means that system removes the voltage spikes or sags, or harmonic distortions in the AC feed with the AC-DC-AC double conversion. USP batteries usually need plenty of space. That is reason why they are typically housed in a separate UPS rooms located on the different floor than servers. The size of an UPS usually varies between hundreds of kilowatts up to 2 MW (Barroso and Hozle 2009 p. 41; Dai et al. 2014 p. 11.)

PDUs are receiving power from UPS systems. PDUs convert and distribute the high voltage power (typically 200-480 V) into many 110 or 220 V circuits, which then feed the actual IT equipment of data centers. Those circuits are protected with their own breaker system. This system is made the way that ground short in a server or a power supply will trip only the breaker for that circuit, not the entire PDU or UPS. A typical PDU is made to supply 75-225 kW of power and feed several 110 or 220 V circuits. In PDUs and UPS the additional redundancy can be achieved by accepting two independent power sources. These sources are typically called A and B side. It is possible to switch between them in the system with the very small delay which guarantees that loss of a one source is not affecting of the power of IT equipment in case of UPS or PDU failures. (Dai et al. 2014 p.11; Barroso and Hölzle 2009 p. 41).

Cooling equipment:
Often used method for data centers cooling is to use computer room air conditioners (CRACs). In the CRAC system cooled air is guided to IT equipment racks through the raised floor (underfloor air supply configuration is shown in the Figure 7). In this system, the air flow travels across the IT equipment removing the exhausted air from the back of the racks.

A typical way of arranging the racks is to install them alternating into rows of "hot and cold aisles". The purpose of this arrangement is to avoid mixing hot and cold air which reduces the cooling efficiency (Dai et al. 2014 p. 11; Barroso and Hölzle 2009 p. 42). In the cooling systems the characteristics of air are utilized: Hot exhaust air being lighter than cold air rises up from the IT equipment and is then recirculated to the CRAC, where it is cooled to right temperature and transferred back to the racks. Since mixing hot and cold air is not desirable, hot and cold aisles are separated with the curtains or hard partitions – this improves air distribution and enhances energy efficiency (Dai et al. 2014 p. 11.)

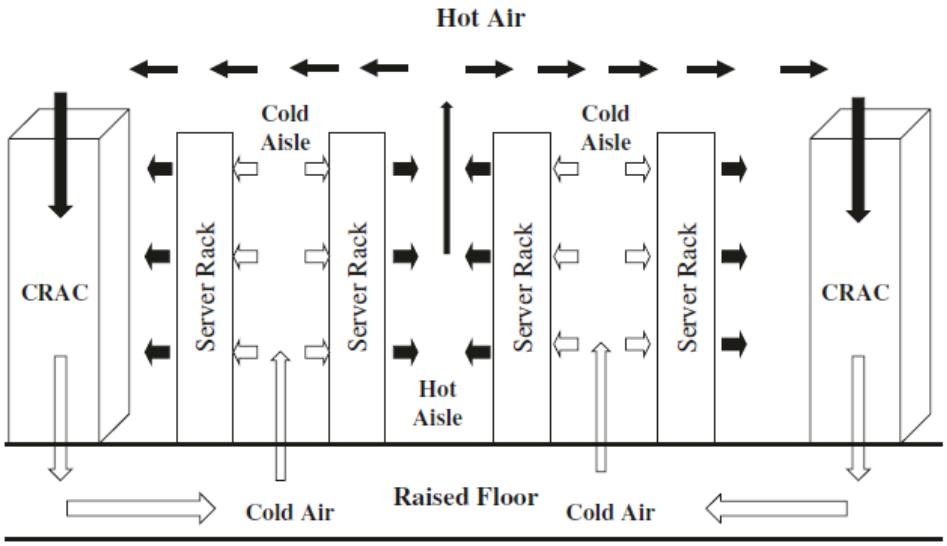

Figure 7: Air circulation in the simple data center with raised floor (underfloor cooling) (Dai et al. 2014 p. 12).

The warm air leaving the cabinets is blown with the fans to the coils in the CRAC units. Those coils contain chilled liquid coolant which cools the heated air which is then transferred back to cabinets. The heated cooling fluid travels from the CRAC to a secondary loop chiller or cooling tower(s) and emits excess heat which is then released to the outside environment. The coolant temperature is normally maintained between 12 to 14 °C, the air leaving the CRAC varies between 16 to 20 °C, and the cold aisle is about 18-22 °C (Dai et al. 2014 p. 12; Barroso et al. 2009 p. 42). There are of course many different ways to arrange the cooling in the data centers[15]. The location and the outside temperature also play a role in the choosing of the used cooling method (Barroso et al. 2009 p. 4.)

IT Equipment:
Data centers include various IT equipment. Typically IT equipment consists of servers, storage devices, and telecommunication equipment like routers and switches (Dai et al. 2014 p. 12; Lettieri 2012 p. 3). Lettieri (2012 p. 3) writes that in the typical data centers these IT equipment are placed into cabinets called racks. A typical rack is about 2 m tall and 0.6 m wide.[16] Normal installation is to organize racks into rows, which increases the cooling efficiency as described earlier.

Data centers storage consist of various parts: Storage area networks, network-attached storage and external hard disk drive (HDD) arrays. Dai et al. (2014 p. 12) say that data

[15] E.g. free cooling solutions are discussed in the Chapters 2.63 and 2.6.4
[16] In the original reference: 7 feet tall and 2 feet wide.

centers have two main functions: first of all they are big data storages and secondly they provide access to this data when requested. Data centers' IT equipment is designed to take care of those operations. Telecommunication equipment (routers and switches) provide the communication between the systems and equipment in the data center but also between the data centers and the outside.

Lettieri (2012 p. 3-4) lists two more components of data centers: building structure and economizers:

Building structure or housing for data center:
Servers need to be housed somewhere. There are many different kinds of solutions for housing data centers from traditional brick or mortal construction to the shipping container solutions. Data centers can be new buildings designed only for the data center purposes or they can be existing buildings that have been retrofitted for the data center use.

Economizers
Economisers or economizers are used to utilize the cold outside air in data center cooling to decrease the costs of cooling. Economizers can be classified into two main categories: air-side and water-side economizers. Both air-side and water-site economizers use the cold outside air to cool the data center.

In the air-side economizers the cooling effect in the data center is achieved by pumping the (cleaned and conditioned) outside air into the data center and IT-equipment. Water-side economizers work slightly different way: In the water-side economizer the cooling of the working fluid in the CRAC unit is achieved without the use of chillers. In the water-side economizer systems the heat exchangers are installed between the CRAC unit and the cooling tower. With the use of both cooling towers and cold outside air, cold water is generated to cool the working fluid in the CRAC unit (the principle of CRACs was explained earlier). In the proper circumstances the use of water-side economizers can replace the use of chillers (Lettieri 2012 p. 6.)

2.6.2 Different ways of operating data centers (business models)

Not all the data centers have the same kind of business model. In fact data center as a term does not describe what kind of business model it is operated or what the characteristics of the facility are (Reichle & De-Massari 2011 p. 20). It is important to understand that not all the data centers are operated the same way and different types of data centers also have slightly different requirements for the infrastructure on site. Following classification to different kind of data centers is based on Rath's (2011) classification. One should note that described business models are generic examples of the different ways of operating data centers and there are also different variations among each business model. Since all the data centers business models are somewhat different not every data centers business model fits for all kinds of businesses. Each of the company should consider what business model fits the best for their own business purposes.

Warehouse-scale
Term Warehouse-Scale computers was originally introduced in 2009 by Hölzle and Barroso in their publication "The Datacenter as a Computer: an Introduction to the Design of Warehouse-Scale Machines". Term refers to the business model of big Internet service producer such as Google, Amazon or Microsoft, providing services for millions of users and

having huge computing needs. Warehouse-scale computers were already discussed earlier in Chapter 2.6. Big Internet operators have invested billions of dollars for those facilities in the past years. According to Rath (2011 p. 7), that type of business model fits operators with the large computing needs and fast-moving business. Warehouse data centers have big needs for the energy infrastructure which have to be taken into account in the site selection phase.

Supercomputer data centers
Supercomputer data centers have slightly different requirements than other types of data centers. Supercomputer data centers need a facility which provides electrical and mechanical systems for extremely dense compute nodes. Supercomputers have very high requirements for cooling due to high-performance computing. Water (liquid)-cooling can be arranged in supercomputers even the way that it extends up to the chip level. Supercomputer data centers are usually single-owner facilities which are designed according to the owner's requirements. However, super computers can be also operated in colocation or wholesale provider's data centers. The fastest supercomputers in Nordic countries are Beskow in Sweden and Sisu in Finland. Those supercomputers are among the top 60 supercomputers in the world (see Top500 2015.)

Single-owner dedicated data center (Enterprise data center)
The majority of the data centers belong to this category. These data centers are owned, operated and controlled by the owner. A great variation of different data centers belong to this category from small server rooms to big facilities with the capacity of megawatts. Rath (2011 p. 7) says that many of the operators currently running their own data centers are searching other business models for their business (e.g. collocation of wholesale options) since maintaining an own data center requires a great number of resources which could be targeted elsewhere. Banks and other financial service producers have been typically owning their own data centers. However, there are already signs that those businesses would start to outsource at least part of their IT in the future (MacSweeney 2014). According to the white paper of Schneider Electric, building an own data center provides smaller total cost of ownership (TCP) than outsourcing (using colocation data center service) when the expected life of a data center is more than five years. In the lifetime of ten years, a new data center may save about 20 percent compared to outsourcing (see Torell and Brown 2014 p. 8.)

Public or private cloud
There are three different delivery models for the cloud: Platform-as-a-Service (PaaS), Infrastructure-as-a-service (IaaS) and Software-as-a-Service (SaaS). Armbrust et al. (2010 p. 51) say that in the data center the hardware and the software are those (components) what we call *cloud.* When a cloud service is designed for the general public (with the principle of pay-as-you-go), it is called public cloud. In this context pay-as-you-go means that the user pays for the amount it uses the service (=cloud) no matter how many servers were used at once (one hour with 1000 servers cost the same as 1000 hours with one server).

Private cloud means that the cloud service is produced for the company itself and it is used to fulfill company's own computing needs. Armbrust et al. (2010 p. 51) tell that cloud computing offers three different aspects which differ from the traditional data center business model:
1. Cloud service users have "infinite" computing resources available on demand without the need for the user to make own provisioning for the future.

2. Companies can start small without having no need for big investments for the hardware in the beginning – the use of cloud can be increased when there is a real need.
3. Computing can be paid for the short term basis – no need to pay when there is no use.

Retail Colocation
Colocation means that data center operator provides basic data center services for the service users/clients (= companies). In the retail colocation business model, the service producer offers power (electricity), cooling, server racks, networking (fiber optic producers' network availability) and facility services. Colocation client (company) rents certain amount of racks or rack space and pays for their electricity use separately. The advantage of colocation service compared to the single-owner model is that client (company) pays only for the space they need and there are no additional capacity like typically in the single-owner solutions. Expanding the data computing and storage capacity is also simple since company can just rent new racks if its requirements for computing grow. The client is also free from the expensive investments to the infrastructure and other equipment which are typically high when opening an own data center. Colocation client/user is also free from the operating costs of the facility itself and can often operate and maintain its servers over the network without physically even going to the facility (Savolainen 2013 p. 21-23; Diamond 2016). Colocation service producers are for example TelecityGroup and Hetzner Online.

Wholesale lease
Wholesale lease means that the data center operator rents floor space (the whole building or part of the building) in a data center facility for the client company (tenant). Data center space is operated and designed according to client company's requirements to answer its business needs (Rath 2011 p. 7.) In the wholesale lease client is responsible for the racks, cabling and other things related to the IT equipment (Savolainen 2013 p. 22). Rath (2011 p. 7) describes that wholesale lease business model is similar to the commercial building lease since the client company (tenant) is able to use e.g. its own electrical, mechanical and security solutions. Wholesale lease arrangements are suitable for the companies having big computing needs and if a company needs more liberties than which are available in the retail colocation solutions. The size of the wholesale solution is typically between 300-500 kW.

2.6.3 Energy consumption in data centers

Data centers are integral part of our modern society. When we have become more reliant on those systems, so have grown the power consumed in ICT and data centers. Greenberg et al. (2006 p. 3) say that data centers can be more than 40 times energy intensive than traditional office buildings, meaning that large data center facilities are closer to industrial buildings than commercial buildings considering their energy usage. The worldwide energy consumption of data centers has been rising in the recent year. Increased energy consumption in data centers has also generated significant interest among the data center operators and energy consumption in data centers has become one of the key interest areas among data center operators (Malkamäki and Ovaska 2012.; Saha 2012 p. 14). Figure 8 shows the expected development in the data centers energy use in the U.S. and globally. Data centers energy consumption rose by 56 percent between 2005 and 2010 (the same increase in consumption as between 2000 and 2005) (Koomey 2011 p. 9; Dai et al. 2014 p. v). Saha (2012 p. 9) describes that the energy consumption of data centers will become a serious issue for the industries and environment in the future. He adds that there has been a great interest to decrease the energy consumption of data centers recently.

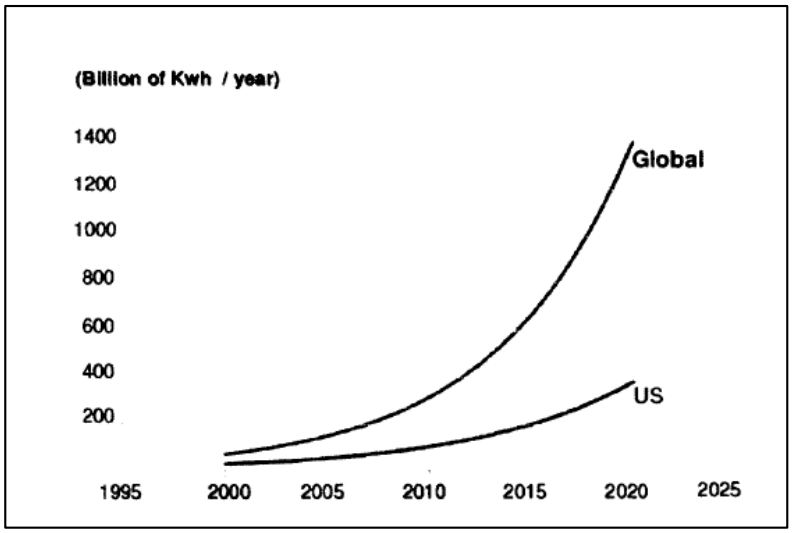

Figure 8. The energy consumption of data centers in the U.S. and globally. Data after 2005 is expected growth, not real development (Parolini 2012 p. 5).

Saha (2012 p. 10) says that the simplest way to lower the data centers energy consumption is to design servers that are more energy efficient. However, even the servers are responsible for the most significant fraction of the energy consumed in data centers there are also other sources in the data centers that use significant amount of electricity. Data centers energy consumption can be divided into three main parts (see Figure 9) which are consuming the biggest share of the energy. Those parts include *servers, network elements (switches and fibers)* and *cooling systems and other elements*. There is a general consensus of those three main elements causing the most of energy consumption in data centers. Still, the size of each part of the total consumption varies quite significantly between different references (see e.g. Saha 2012 p. 9-10; Dai et al. 2014 p. 10; Johnson and Marker 2009 p. 7; Almoli et al. 2012). According to Saha (2012 p. 11) servers consume 55 % of the total power consumption when the cooling (and others) is responsible for about 25 % of the total power consumption and the rest 20 % comes from the network elements. It is necessary to note that there is great variation between different data centers and the technology used so the shares of different parts should be seen only as estimations.

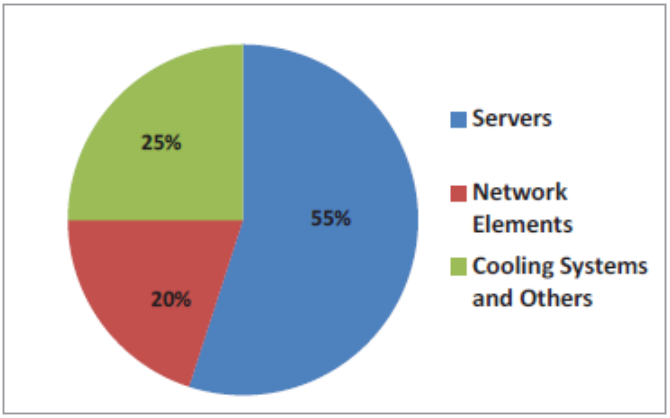

Figure 9: Data center energy consumption (Saha 2012 p. 10)

In order to understand how the energy is used in the data centers, there has to be ways to measure energy consumption. Wright (2014) describes that the best practice for doing that is the use of energy efficiency metrics. To analyze the data centers energy efficiency, The

Green Grid (industry group focused on data centers energy efficiency) has created the *Power Usage Effectiveness* (PUE) metric for data centers.

PUE for data centers is defined *"as the ratio of total energy consumption of a data center to the total energy consumed by the computing devices of the data center*. "*(Saha 2012 p. 10)*

PUE is the most commonly used metric for data centers energy efficiency (Wright 2014). There has been great effort among some data center industry companies to get PUE values of their data centers close to 1.0 which is the theoretical minimum value of PUE. Having the PUE value of 1.0 would mean that the electricity in the data center is used only for the IT equipment. Google for example has been making continuous progress with its data centers efficiency and its results have been improving constantly every year as seen from Figure 10 (Google Data Centers 2015)[17]. According to Uptime Institutes' (2014a) "Data Center Industry Survey 2014" there have been significant improvements in the average PUEs among their network members (consisting of data center operators and IT practitioners); the average PUE improved from 2.5 in 2007 to 1.7 in 2014.

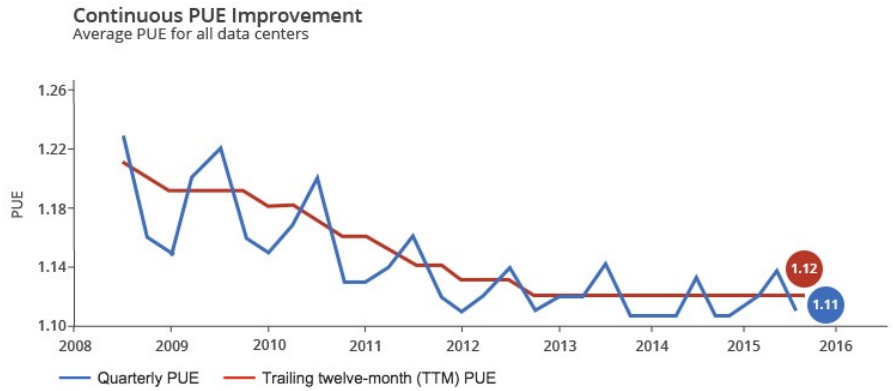

Figure 10: PUE development in the data centers of Google (Google Data Centers 2015).

There are also other metrics to evaluate the energy efficiency of data centers. Another commonly used metric for data centers energy efficiency evaluation is *Data Center infrastructure Efficiency* (DCIE) which is reciprocal of PUE and is expressed as a percentage value. The higher the percentage value is, the more efficient is the data center (Wright 2014; Tech Target 2009.)

Formulas for calculating different efficiency metrics (Wright 2014):

$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ Power}$$

$$DCIE = \frac{IT\ Equipment\ Power}{Total\ Facility\ Power} * 100\ \%$$

Saha (2012 p. 11) says that in order to improve the data centers energy efficiency, the main attention is often targeted toward the main consumption elements: servers, cooling or network elements. According to Uptime institute's (2013) "Data Center Industry Survey

[17] Google's PUE values have actually remained similar for a few years – Google seems to have already achieved the level where the yearly improvements have ended.

2013", the most of the improvements in PUE values have been based on simple modifications such as preventing bypass airflows, installing blanking panels for racks or sealing openings in the raised floor. Those so called easy and low-capital solutions have already been broadly adopted among data center operators and in the future potential PUE improvements will be based on more sophisticated and expensive modifications.

Mulay (2009 p. 7) tells that until recently, the reliability of data centers was the first priority for data center operators and energy efficiency was not playing a major role. However, later the importance of the energy efficiency in the data centers has increased. Improvements in the energy efficiency bring also many benefits for the data center operators. Mulay (2009) names the benefits of better energy efficiency being smaller operating costs, reduced dependency on fossil fuels and smaller amount of greenhouse gas emissions of the operating the data center just to name a few.

Shehabi et al. (2011 p. 997) say that the trend of consolidating data centers will influence more likely by the better energy efficiency of data centers in the future since big data centers are typically more energy efficient than smaller ones. The location of data centers can also play a bigger role in the future than nowadays: Some of the data centers will be located to colder geographic regions where the chilly climate enables the use of *free cooling* solutions to spare in the energy costs. That kind of development is more likely to be realized especially among the large data center facilities. According to Shehabi et al. (2011), in the large data center facilities it is possible to get more benefits from the use of economizers than in the small data center facilities. Shehabi et al. (2010 p. 997) ponder that the role of regional climate differences can grow in the future also in managing greenhouse gas emissions.

Malkamäki and Ovaska (2012) propose that the solar power and the use of economizers can become common in the future when trying to improve the energy efficiency of data centers. Malkamäki and Ovaska (2012) say, however, that the use of solar power and economizers together is although complicated because areas with the high solar energy potential are often not very optimal for economizers and free cooling and vice versa.

2.6.4 Choosing a location for a data center

There are numerous issues which have to be taken into consideration when choosing a location for a data center. According to Spafford (2009 p. 50), the primary drivers when choosing a location for data centers are cooling, energy costs and energy availability. However, behind those main drivers there are many other dimensions to be considered and different data center operators can prioritize other factors. In this chapter different criteria having influence on choosing the location for data centers are described. Different criteria are described by the general principles. When looking at the list, it is good to notice that different factors are not in any order and different organizations can prefer different factors than shown below.

Climate:
As mentioned in the previous Chapter 2.6.3, cooling is playing a major role in the data centers operations but also in their energy efficiency. Cooling is so important in data centers because the higher the temperature rises, so does the component failure rate. According to that fact it is beneficial to choose the location for a data center in the place where the climate is chilly since it decreases the need for cooling (in case the outside air is utilized in cooling.) (Spafford 2009 p. 50.) Dai et al. (2014 p. 57) say that the climate profile is a very critical

factor when choosing the data center location especially when free cooling solutions and economizers are utilized.

Dai et al. (2014 p. 53-56) write that cool locations enable the use of economizers and free cooling from the environment. Mild weather fits best for the airside economizers and cold conditions can maximize the benefits of the waterside economizers. However, when using the airside economizers the humidity conditions have to be considered because high humidity can affect negatively on the overall systems reliability. Cold locations are not always ideal for *free air cooling* solutions because of the high humidity in the air which can limit the use of those applications even the temperature of the air would be ideal for data center cooling.

Spafford (2009 p. 50) writes that reducing the temperature in the data center is not an added value expenditure so if the cooling costs can be reduced only by choosing a convenient location (= cold location), it is beneficial for the business. For example Facebook names cold climate as one of their top priorities in the site selection (Clipp et al. 2014 p. 16).

Energy costs
Energy costs have a big effect on the ongoing operation costs of data centers. It is estimated that energy costs in the data centers may exceed the costs of IT in the future (Mittal 2014 p. 3). Energy costs can vary significantly between different locations even inside the country. Spafford (2009 p. 50-51) suggests that the trend data of the energy prices should be collected from the different regions and the possible energy prices estimated before choosing the location to know the "real" energy prices. Clipp et al. (2014 p. 26) say that especially important energy costs are for the global Internet companies who are operating large data center facilities (mega data centers).

Clipp et al. (2014 p. 26) state in their white paper that in the large-scale data centers the energy consumption is responsible for at least half of the total ongoing operational costs. For example in the Facebook's data center in Luleå, Sweden, the energy costs make about 65 percent of the ongoing operational expenses.

Energy availability and energy sources
It is essential to choose the location for data center by considering the energy availability in the region. Important is to clarify, how robust is the power grid and how easily the energy is available for the data center use. Spafford (2009 p. 51) advises that the survey should be made by interviewing local authorities but also other energy users in case the data center operator is not very familiar with the region. Especially vital is to get familiar with the experiences of companies in energy-intensive fields (e.g. foundries, glass producers and forest industry).

Malkamäki and Ovaska (2012) say that green energy sources are becoming important in the powering of data centers in the future. Especially wind and solar power are rising their importance. With both of those energy sources there are still some problems to be solved: Wind power for example is suffering from big variation in the production and energy storages are needed to balance fluctuation in the productions which then increases the costs significantly. Malkamäki and Ovaska (2012) state that solar energy seems to be more predictable than wind power by having predictable pattern with diurnal and annual cycles.

On the other hand solar power has its own weaknesses. Especially hard is to combine free cooling and big potential for solar power.

Tax and economic incentives
CBRE (2010) says in their white paper that economic incentives are used to lure businesses (e.g. data centers) that will significantly expand the tax base, employ people, have a catalytic effect on local suppliers and create new work together with local wealth. However, economic incentives are not turning bad locations into good ones but they can be important in the decision making if two different regions have relatively similar conditions. The three main functions of economic incentives are to address cost disadvantages, revitalize regional economies facing problems and produce favorable economic activity.

Tax incentives are offered by the state and local governments for the data center operators to start operating their business in the region. Tax incentives work similar way as other incentives and can help for example by covering part of the building or operating costs. (Spafford 2009 p. 52). Lenio (2011) argues that incentives are not the key issues considered in the beginning of the site selection process but they are often considered later in the process after the most critical issues have been evaluated. Incentives can also ease the decision making if there are no major differences between different locations and only another one offers them. The role of the incentives is especially important in the U.S. where some states have special incentives programs for data center operations.

Regulations and political environment
Spafford (2009 p. 52) argues that the political situation in the data center location should be stable. Secure political situation guarantees that the data center operations and the data host in the data centers are safe and secured. Benáček et al. (2014) found in their research that such factors as price stability, absence of price control, low inflation and investment policies indicator often had positive effect on foreign direct investments (FDI). Other positive factors for the investors were low regulations, low corruption and effective public administration. Benáček et al. (2014) argue that countries having transparent and efficient institutions are also more likely to experience higher levels of FDI and prosperity compared to countries with weaker institutions.

Also, countries with high political risks are more likely less attractive among foreign investors than countries with stable political situation (Benáček et al. (2014) p. 630). Multilateral Investment Guarantee Agency (MIGA) has listed the biggest concerns of foreign investors in the developing countries (see Figure 11). Political risk was listed as the second biggest concern, right after the macroeconomic stability (World Investment and Political Risk 2013). Figure shows that even the political risk would not be among top decision factors in the investments, high political risk at least rises the concern among investors. World Banks ranks countries based on their political stability yearly: in the ranking of 2014 Lichtenstein placed first and Syria the last among 191 countries (The GlobalEconomy.com 2016).

Nissilä et al. (2015 p. 6) highlight that it is also a big asset for a data center business in a country if the regulations are stable and predictable. Since data travels throughout the countries and borders, it is an advantage if the data center is located in the country where data enjoys legal protection.

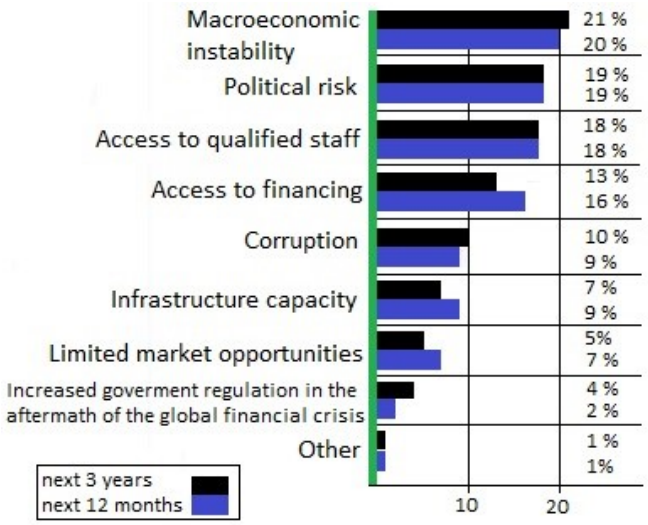

Figure 11: The biggest concerns of investors in the developing economies. (World Investment and Political Risk 2013).

Natural disasters

The chosen location for data center should be in a place where the possibility for a natural disaster is relatively small. All kind of natural risks (e.g. snowstorms, hurricanes, thunders, tornados, earthquakes etc.) can disturb the power availability or harm data centers other way (Spafford 2009 p. 52; Lenio 2011 p. 1). Nissilä et al. (2015 p. 5) write that the geological location and solid bedrock soil are other important issues to take into account if operators want to reduce the risk of disasters that could damage data centers infrastructure.

Spafford (2009 p. 52) tells that when choosing a location for data center it is important to make proper risk assessment to identify all the possible risks of the environment including the risk related to environmental conditions

Internet connectivity

Connectivity is very important for data centers and one of the primary strategic drivers behind the data center site selection (Lenio 2011 p. 1). Data centers have to be connected with the users of the data center services as well as with the other data centers (Dai et al. 2014 p. 12). In the connectivity the network speed plays the most important role. The network speed is measured with the latency and bandwidth (Nissilä et al. 2015 p. 4). Low latency is especially important in certain industries such as finance and banking sectors.

Market size:

The market size (population size and GDP) is an important factor for the foreign direct investments (FDI). (Benáček et. al. (2014 p. 628) write that modern trade theories highlight the increased returns to scale, which can be achieved by making investments to countries with the big market even it would need costly hiring of local labor. Benáček et. al. (2014) argue that market size together with the growth potential are very important for foreign investments.

In the data center business market size is not necessarily playing very important role for all business models. Only small portion of the data center services are extremely latency critical (e.g. finance and banking sector) and many cloud services for example can and are often handled from the remote distance to the user(s). Still, colocation services are more likely to

benefit big domestic markets because then customers are close to the service producer. This fact can affect on the attractiveness of the regions with relatively small domestic markets (e.g. Nordic countries).

2.6.5 Classifying locations for data centers

As the previous chapter showed, there are many different factors being important when choosing the location for data centers. In fact, it is not necessarily important to set those factors in order since different data center operators are making their decisions based on their own business needs. However, there are some organizations ranking countries in order based on the possible risk factors or other relevant criteria affecting data center operations. One of the publications is "Data Centre Risk Index" where different countries are ranked in order to address which countries have the smallest risk for data center operators (to run the business). The ranking is based on the macro level examination so even some countries would get poor scores in the index it does not necessary mean that all the micro level locations inside the country are poor.

The Data Centre Risk Index is based on tier weighting system where different categories have different weight in the assessment. Tier system has three sub categories (tiers 1, 2 and 3) including different factors which construct the total result (Table 1):

Table 1: Data Centre Risk Index tier ranking. Table is based on the tier weighting system (Data Centre Risk Index 2012).

Tier 1		Tier 2		Tier 3	
60 %		35 %		5 %	
Energy cost (per kWh)	33 %	Corporation tax	12 %	GDP per capita	25 %
International internal bandwidth	33 %	cost of labour/hour	8 %	Inflation	25 %
Ease of doing business	33 %	Political stability	20 %	Water availability per capita	50 %
		Sustainability (% energy from alternatives)	10 %		
		Natural disasters	25 %		
		Population education level	10 %		
		Energy security	15 %		

Typically the U.S. and UK have been top countries in the ranking. Their advantages are especially the tier 1 sub categories *International internal bandwidth* and *ease of doing business* where they both usually rank high. Other high ranked countries in the Data Centre Risk Index 2013 where Sweden, Germany and Canada (more about the index see Data Centre Risk Index 2013).

It is good to notice that companies are making their decisions of the data center location by considering their own priorities, not just by the possibility of risks in the site location.[18] For example Google describes the factors why it has chosen certain locations for its data centers. Three of the most common factors in the Google's decision making have been:

1. The right combination of energy infrastructure
2. Developable land for the data center
3. Available workforce for the data center (Google Data Centers 2014.)

[18] It is important to note that Data Centre Risk Index also evaluates other factors in addition to the risk of business despite the slightly misleading name of the index.

Clipp et al. (2014 p. 16) describe in their white paper the decision making of Facebook. Report tells that Facebook decided to locate its data center to Luleå, Sweden because of the following factors (factors are not arranged in any order):

1. Reliable power grid
2. Renewable energy
3. Robust fiber infrastructure
4. Cold climate
5. Low risk for natural disasters
6. National commitment and investment
7. Local competence and an ICT-trained workforce

Notable is that the criteria of these both organizations are relatively similar to each other. It is easy to point out that since data centers use huge amounts of energy, energy infrastructure plays a big role in the decision making. For the same reason the electricity prices also have very important role for the data center operators (Clipp et al. 2014 p. 26.)

Both of the organizations also name the (educated) workforce as one of their top priorities in the site selection. This is one factor which was not listed in the previous chapter being important in the selecting location for data centers. However, since large data centers require relatively lot of workers (compared to small data centers), big data center operators might find advantages of recruiting local workforce at least to some extent. Local workforce can be seen important because they know the local conditions, legislation and language just to name a few of the reasons which support the idea of recruiting local workforce.

The availability of fiber optic connections is a very fundamental factor for all data center operators. Data centers have to be connected with the users of the data center services but also with the other data centers by multiple fiber optic links. In addition, fiber optic connections from the data center location (= host country) should be provided by multiple connection links to other countries (Savolainen, 2013 p. 17.) Despite Google is not naming fiber optic connections for their top priorities, robust fiber optic infrastructure can be considered extremely important also for them – both Google and Facebook produce similar Internet related services.

2.6.6 Tier classification for data centers

Different organizations are using data centers for different business purposes and have different requirements for their performance. Uptime Institute created in the mid-1990s *four-step-tier-certifying-system* for evaluating different data center facilities according to their infrastructure performance (See Uptime Institute 2016). This certifying system evaluates data centers design, facilities and operations, and has become a global standard (certifications are available in 71 countries in the world) for evaluating data centers infrastructure (Stansberry 2014). Tier system is progressive, meaning that higher tiers fulfill the requirements of lower tiers. Tier system is shown in the Table 2.

Table 2: Tier classification system for data centers (Uptime Institute 2014b; Turner et al. 2006a).

TIER	SITE AVAILABILITY	DESCRIPTION	OTHER RELEVANT INFORMATION
TIER I: Basic Capacity	99,671 %	Provides dedicated site infrastructure beyond office settings: • Site has dedicated place for IT-systems: • Has UPS to filter power spikes, sags, and momentary outtakes • Engine generator for protecting IT functions from power outage	• Cooling equipment are running also outside the normal office hours
TIER II: Redundant Capacity components	99,749 %	Includes redundant power and cooling components to provide better maintenance opportunities and increased safety against IT process disruptions redundant components include: • UPS modules • Chillers • Pumps • Engine generators	
TIER III: Concurrently Maintenance	99,982 %	Has redundant delivery path for power and cooling • Enables to shut down components without having an impact on IT operation.	• Equipment replacements or maintenance require no shutdowns • Unexpected event can cause disruptions • During the maintenance, risk for service disruption rises
TIER IV: Fault tolerance	99,995 %	All computer hardware have dual power inputs	• Maintenance can be done without disruptions • can sustain at least one worst-case, unplanned failure

Table 2 shows that the complexity and reliability of the data center facility rises with the tier level tier I being the simplest and tier IV being the most complex and reliable (Figure 12). Unfortunately higher complexity and reliability mean also more construction and operating cost and more complexity in operating of data center. Higher tier does not necessary mean that the data center is any way "better" than the one with the lower tier and client needs define the right type of data center for the business. However, the reliability of the system rises with the tier so the more critical factor the reliability is for the business the higher should be the tier (Arno et al. 2012 p. 779). In the end data center operator has to determine which tier level suit the best for its own business – i.e. what are the availability objectives and how much IT services are used in the daily business.

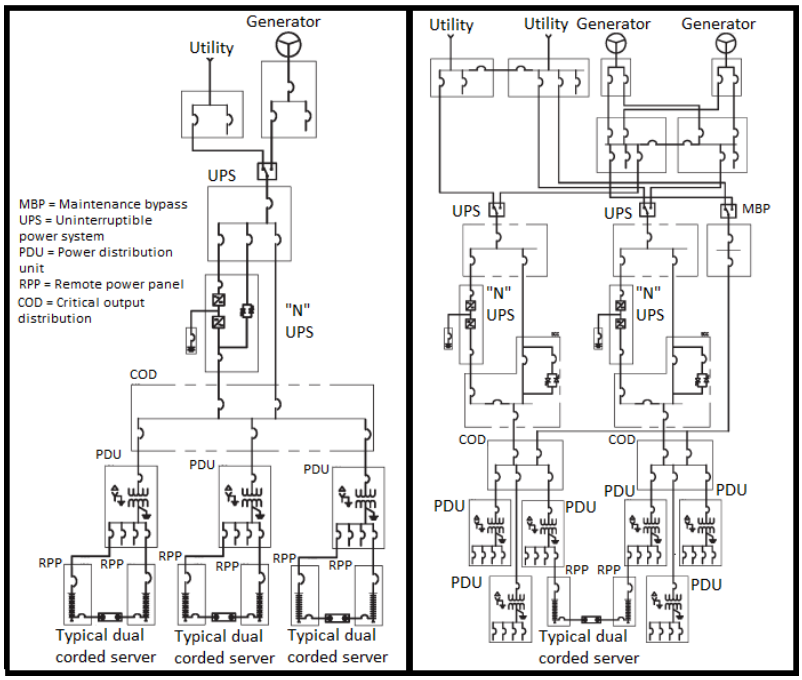

Figure 12: Different tier configurations: Tier 1-N (left) and Tier 4-2N (right). ("N" means the number of generators) (Arno et al. 2012 p. 779, 781).

Turner et al. (2006b p. 6) say in their white paper that those owners who choose Tier I or II solutions to support their IT technology are typically owners searching solutions to address short term data center requirements. Those operations are often driven by the (lower) purchasing price and time-to-market more than life-cycle costs or availability requirements. Owners choosing Tier III and IV solutions often search for a longer-term solutions for their IT and have bigger needs for the availability.

Turner et al. (2006b p. 7) explain that Tier I and Tier II suit for example for small businesses with relatively low requirements for IT and no need for offering 24/7 service for the clients. In contrast Tier IV configurations are suitable for companies having big needs for the information technology or companies using IT as their competitive advantage. Tier IV suits companies operating in the highly competitive international markets and having the need to offer service "24 by forever". Tier IV business is often based on the E-commerce, market transactions or financial settlement processes. Tier IV is justified also for companies operating Internet related services or to colocation providers having some service promises of the quality and reliability of the service. Tier III fit for owners having big IT needs but being able to tolerate the possibility of unexpected failures causing small pauses in availability.

Savolainen (2013 p. 19) notes that tier classification system is only considering the basic needs for data centers such as the redundancy and fault-tolerance of the electricity and cooling hardware. He says that the classification is not concentrating on the characteristics such as communication network, security, operations or data center management which are, however, linked to the reliability and availability of the data centers. Savolainen (2013) criticizes also the tier classification for not taking into account the redundancy build in the software which has become an important factor after the spread of cloud computing.

Tier classification can be used as a guideline when designing a data center and estimating the future costs of data center construction and operating. It can also help i.e. colocation providers to convince their clients about the reliability of the data center service. Still, the actual needs for data center service availability and reliability should always define what kind of data center design is justified to one's own business. A higher tier always means the bigger construction and operation cost due to multiple, parallel components. (Savolainen 2013 p. 19.)

2.6.7 The data center market

Even many references are speaking about the rapid growth in the data center market, it is relatively difficult to find concrete numerical values of the growth in the whole global data center market. However, some research organizations are making their estimations about the data center market size. Unfortunately most of the newest reports are not available free of charge or they are available only for certain interest groups. Thus, estimations of the global data center market size are based on reports which were publicly available without any additional payments.

DLA Pipers' (2014 p. 5) "2014 Global Data Centre Market Report" highlights that current macro trends are driving the growth in the data center market. The report describes that data center market keeps growing and demand for data centers continues to rise despite the recent turbulence in the economic climate around the world. Report names three key factors driving the market growth:

1. Companies consolidating their server rooms into bigger centralized sites
2. Virtualization and compression technology enabling companies to use more data hungry applications
3. Growth in the cloud based applications

In 2011, Belady (2011) estimated that new data center construction investments were globally about 50 billion dollars (see Figure 13). Figure 13 shows that Belady (2011) expects significant growth in the market by the year 2020 when the size of new data center investment is estimated to be a bit less than 80 billion dollars. This projection was made with the estimation of an average building cost being 6 M$/MW.

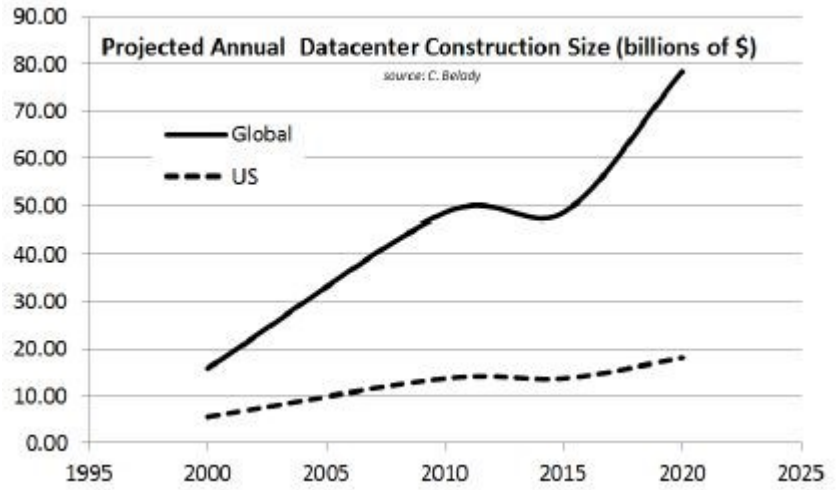

Figure 13: The market size of new data center investments (Belady 2011 p. 7).

CDC Intelligence's (2013 p. 2) "2013 Census Report: Global Data Center Investment 2013" estimated that the size of data center investments in 2013 were about 151 billion $. In comparison to Belady (2011), the research of CDC Intelligence takes into account also the investments on the existing facilities not just on new constructions which explains the big difference in the values. Research shows that the biggest growth in the data centers investments was occurring in Latin America which faced 12.2 percent growth between 2012 and 2013. The growth in Europe was 6.2 percent, Poland being the fastest growing market with the growth rate of 40 percent. Overall the global data center market investments were growing 8 percent in 2012-2013.

According to Worn (2014 p. 21), between 2012 and 2013 most of the investments in data centers were made in the geographic area of Europe plus Russia. The second biggest number of investments were made in North America. Among the individual countries most of the investments were made in the U.S. (24.2 %) and the second most in Japan (10.5 %). During the same time period investments in the Nordic countries rose by 17 percent (CDC Intelligence 2013 p. 4).

Future growth will be also significant in the data centers constructions. Technavio (2015) estimates in their report that the data center construction market grows by 10 % annually between the years 2015 and 2019. However, Uptime Institute (2013 p. 7) predicted that the data center construction might slow down a bit in the near future. Unfortunately Uptime Institute's newer report from 2014 is no more discussing if the construction in the data center market has really slowed down or if it was only contemporary turn (Uptime Institute 2014). Still, the report of Uptime institute from 2013 described that the budgets of data center operators were in a rise which can be seen as an opposite statement to the decreasing construction in the future.

Savolainen (2013 p. 34) divides the data center construction market into three main segments: traditional enterprise segment, colocation segment and Internet company segment.

Traditional enterprise segment
Traditional enterprise data centers are those data centers which are owned by the different organizations. Banks or other financial institutions needing high security level for their data are typical examples of the owners of data centers this kind. Those organizations still often construct their own data centers. According to Uptime Institute (2014a), more than half of the enterprise data center operators had increased their investments in their data centers during the research year. This is relatively fast growth rate. Still, it is somewhat smaller in comparison with other types of data centers. On the other hand Uptime Institute (2014a) report shows that there are no signs that enterprise data centers would disappear any time soon. However, many of the companies having own data centers are already hosting some percentage of their services off-house, in multi-tenant data centers (MTDC), cloud or other third-party environments.

Colocation segment
Colocation data centers are data centers where data center operator provides data center space for other companies to rent for their IT-equipment (see more information about different service models in the Chapter 2.6.2). According to Uptime Institute's (2013) report, the collocation/multi-tenant segment is the fastest growing segment in the data center

construction market. The main colocation markets are located in the big financial centers around the world. This is a consequence of the high latency requirements of certain businesses. Especially important low latency is for the finance and banking sector. In Europe, the main colocation markets are London, Frankfurt, Paris and Amsterdam. Figure 14 shows the growth of colocation market in Europe between 2005 and 2014 (CBRE Marketview 2014).

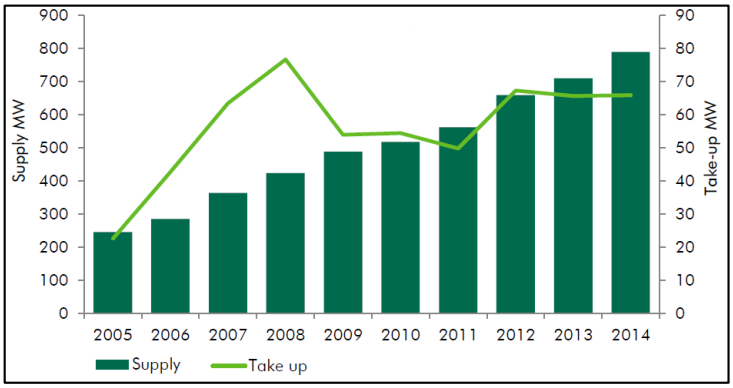

Figure 14: European Colocation supply and take-ups in Q4 2014 (CBRE Marketview 2014 p. 1)

Internet company segment

A big share of the data center construction investments comes from the big Internet operators (the so called content and application providers). According to Abecassis et al. (2014 p. 1) report, these operators invest billions of dollars annually for the combination of facilities (data centers), fiber networks, servers and routers. Those investments have been also in a constant growth since the use of Internet related services (including services of those companies) has been growing significantly. In this segment, there are companies like Google, Spotify, Amazon, Yandex and Facebook. However, the amount of companies belonging to this segment is quite limited. Most of these service providers host their own data centers but some companies have chosen another strategy and use collocation solutions.

2.6.8 The need for data centers

There has been a rapid growth in the number of data centers in the recent years. This growth has been fueled by the increasing demand for services provided in the data centers like data processing, storage and cloud computing (Parolini 2012 p. 4; Yogendra et al. 2012 p. 1; Saha 2012 p. 2). Increased data processing, grown storage space and cloud computing solutions have enabled the increase in many Internet related services such as electronic transactions, Internet shopping, Internet-based entertainment and communication, electronic records for healthcare, satellite navigation and electronic shipment tracking just to name a few (Yogendra et al. 2012 p. 2).

The amount of Internet users has also been growing significantly. According to World Economic Forum (2014), in 2014 there were more than 2.5 billion Internet users in the world, meaning that about one third of the world's population is already connected to Internet. This amount is constantly growing and by the year 2020 there should be already about 4 billion Internet users. The amount of the information (data) in the Internet is also growing together with the growing user amounts. There are already about one billion different websites which is 5 times the amount in 2010 (Internet live stats 2016).

Saha (2012 p. 2) says that the major reason for the growing need for the data centers has been the huge growth in Computing-as-a-Service (CaaS) and cloud-based applications. Examples of cloud-based services are search engines like Google and Bing, video hosting services such as YouTube and Netflix, social networks (Facebook, Google+, Twitter) and large-scale computation applications (e.g. data mining, bioinformatics, indexing). Those services require large scale as well as high-performance computing and storage infrastructure. Facebook and YouTube for example are reaching millions of users daily who upload millions of pictures, videos and other content to the services. To handle those huge amounts of data, the size of data centers has also been forced to grow in size and some of the data centers have grown into huge complexes with more than 100 000 servers.

Our society is also producing all the time greater amount of data. This data is created everywhere and stored in digital format to different systems such as companies' own networks, governmental information systems, health care data bases, mobile phones and social media just to name a few. This huge amount of information is known as "big data". Wikipedia defines big data as follows:

"Big data is a broad term for data sets so large or complex that traditional data processing applications are inadequate" (Wikipedia contributors 2016b).

There are many other versions to define "big data". For example Hurwitz et al. (2013 p. 11) define that big data is any kind of data source that has three typical characteristics:

1. Extremely large volume of data
2. Extremely high velocity of data
3. Extremely wide variety of data

Volume:
The current volume of data is something different to what we have been used to in the past. Social media is producing huge amounts of unstructured data every second, minute and hour 24/7. There are also multiple sensors in the different devices producing new information, machines interact with each other and the revolution of the Internet of Things (IoT) is around the next corner. Large volume of data brings challenges for finding and identifying all the relevant data among the large volume (Tavberidze 2014 p. 505).

Velocity:
The speed of data streaming from different sources is huge and it should be dealt within a timely manner. It is often not enough just to be able to deal with huge amount of data, one should also be able to manage it at a high speed (Hurwitz et al. 2013 p. 32.) Being able to react fast enough for the huge velocity of data sets some big challenges for organizations. Especially a real-time approach is important when the answer to the problem is time sensitive or business critical (Hurwitz et al. 2013 p. 32).

Variety:
Data comes in many formats (e.g. text, numbers, images, videos, maps etc.) which sets huge challenges for organizations' data management (Tavberidze 2014 p. 505). Hurwitz et al. (2013 p. 21, 25) say that some of this growing amount of data are not very organized such as data coming from machines or sensors – which can cause difficulties to data management. Also, some of the sources of big data did not exist before: New sources of big data are for

example such as data generated in sensors, smartphones and tablets. Being able to find connections and correlations between different data formats has become very important in the era of big data. However, due to better networks and data storages there are ways to capture and analyze all the data collected which was impossible in the past.

Big data offer organizations big possibilities: It allows them to gather, store, manage and process big data masses in the right time and speed and get the better understanding about the "big picture" than never before (Liikenne- ja viestintäministeriö 2013; Hurwitz et al. 2013 p. 11, 24, 244). This is a huge opportunity for the companies to create new business and innovative solutions when huge amount of data is all the time available and relatively easily accessed (Hurwitz et al. 2013 p. 1). On the other hand big data creates challenges for using it efficient way.

The speed of the data expansion is fast. According to Turner et al. (2014 p. 1) white paper, the amount of data is growing by 40 percent a year. This growth is fueled not just by the growth of the people and companies doing things online, but also because more devices and "things" are online. Turner et al. (2014 p. 3) name three big spurts in the recent years, which have accelerated the data growth significantly: The first spurt was when digital cameras replaced film versions, the second one when analog telephone went digital and the third one when analog TV changed into digital. Turner et al. (2014 p. 3) say that the fourth spurt is now coming in the form of Internet of Things (IoT). IoT means basically that more and more devices will be connected to Internet and they can be controlled and monitored online. Those devices are also able to communicate with each other and the environment and are able to adapt their actions to different environments. In conclusion, due to IoT the overall intelligence of the machines grows. According to Turner et al. (2014), IoT is already having an impact on the data growth and its importance will grow significantly in the future.

The increased amount of data is setting challenges also to the digital infrastructure. Nissilä et al. (2015 p. 8) tell that there is a big need for coping with this fast growth of data by building new data centers. Cisco (2014 p. 10) expects in its white paper, that the data centers workload is moving in the greater amount into cloud and in 2018 already 78 percent of the all data centers workload will be processed in the cloud data centers. The current amount of data centers in the world is around 200 000 with the total server space capacity being 64 million square meters. The size of these facilities can range from small rooms to industry size buildings (Nissilä et al 2015 p. 8). Cisco (2014 p. 8) expects that mean annual growth in data centers traffic will be 23 percent most of this being growth in the cloud data centers. Nissilä et al. (2015 p. 8) state that the size of the data centers, especially with the cloud operators, is more likely to get bigger in the future.

On the other hand, one could say that the computing power of the servers increases every year and same operations can be performed with fewer servers. This is of course evident development. Still, the speed of the data growth is even faster than the increase in the computing power so more data centers have to be built to cover the future need (Maney 2013; Savolainen 2013 p. 32; Khosrow-Pour 2015 p. 367.) Server investment costs are also high, so there is no possibility to update servers in data centers all the time.

Savolainen (2013 p. 32) says that the growth of Internet related services and the need for data center services has been explained with the Jevons' Paradox: the idea behind the paradox is basically that at the same time when the efficiency improves the demand grows.

This perception was made when Jevon observed the coal market in the 19th century: At the same time when the efficiency of coal use improved and allowed to produce more goods per unit of coal, the total coal consumption increased (York 2006 p. 143.) In the data center context paradox means that when the computing efficiency increases, the demand for computing and data center related services increases even more. Savolainen (2013 p. 32) says that one could argue against the paradox by saying that when the efficiency of data center service goes up decreases the overall footprint of data centers because the same service is possible to produce by fewer resources. However, this is not what might happen because of the rebound effect: For example if one spares money (and environment) by investing in a new energy-efficient car, one might use the spared fuel money for example to buying a trip abroad or just changing the driving habits and using car more often than before (Maxwell et al. p. 28-32.)

In conclusion of the chapter, the data center market will grow in the future especially due to growth in the new Internet related services and IoT. However, constant development happens also in the technology and computing becomes more efficient, making existing data centers more efficient than before. Still, many reports show that data center market is more likely to grow quite rapidly still and new data center investments will be made to satisfy the growing demand for Internet related services and companies' increased computing needs.

2.6.9 Brownfields (old industrial sites) as location for data centers

As described in the Chapter *2.4.2 Brownfield possibilities and the typical development process* earlier, there have been different ways to develop brownfield sites. In this thesis, the scope was to clarify brownfields potential in the data center use. There are some examples of old industrial sites (brownfields), which have been harnessed for the data center use. On the other hand, there is not much, if any academic research which concentrates only on this specific issue. However, we can assume that most of the same principles which exist in general brownfield development exist also when developing brownfields into data center use.

International cloud operator RiverMeadow (2013) describes in their white paper, that cost saving has become even more important than before in the highly competitive world and all industries, businesses and companies are finding ways to spare costs. Data center projects are often costly, but also limited time and other resources are setting challenges to the projects. Being able to avoid some of the costs and spare time and effort is more than desired. In this context, brownfields have become into consideration when choosing proper sites for data centers.

Data center facilities have certain needs for their location (most of which have been described in the Chapter 2.6.4). Important characteristics of the physical environment (without taking into account the geographical location) are for example electricity availability, Internet connectivity (fiber optic connections), availability of water (for cooling), secure environment and good transportation infrastructure. Considering the needs of data centers, many old industrial sites such as paper mills and other heavy industry halls and factories share many of those mentioned characteristics since they are also important factors for many other industries than just data centers.

Paper mills and metal industry sites for example have ready-made energy and transportation infrastructure (sometimes also good fiber optic connections) and sites are usually well

protected. Sites often fulfill the needs of data centers by many other means too. As described in the first chapters of the thesis, due to restructuring development those sites have now been freed in many regions and offer currently potential location for data centers or other similar functions. Google for example say that they chose an old paper mill (brownfield) in Hamina (shown in the Figure 15) for their data center location because of "*the right combination of energy infrastructure*, *developable land and available workforce for data center"* (Google Data Centers 2014).

Google's example shows that brownfields have potential of becoming locations for data centers.

Figure 15: Google's data center in Hamina. Data center was built in the old paper mill (Google Palvelinkeskukset_a)

Lange and McNeil (2004b p. 107) found several factors to be considered in the successful brownfield development. Those factors included:

- Time
- Cost
- Community support
- Land use
- Infrastructure
- Cooperative banking institutions
- Support from the political side
- Financial incentives
- Environmental cleanup levels
- Jobs (creation)

In case of data centers the same characteristics are more likely to be highlighted during the site selection process.

Brownfields become true competitors for greenfield sites when most of the factors of Lange and McNeil (2004b) are giving the positive answer when considering certain brownfield site. If a brownfield site has a good combination of characteristics like low price, proper planning, good macro and micro location, low construction costs (investor can e.g. spare in costs by using the old good conditioned infrastructure), possibility to start construction in a tight

schedule and low or zero remediation cost, brownfield site is more likely to become a reasonable option for the greenfield sites (Lange and McNeil 2004b p. 104-107). If brownfield development is also eased with some financial incentives or community support, raises it brownfield sites as true competitors to the greenfields.

According to Lange and McNeil (2004b p. 104-107), site specific criteria such as size, distance to the airport or the central city, rail access or water frontage have not been playing a significant role in the brownfield development. One might argue that in the data center context some of those factors might have a significant role. The size of the site for example is important especially if the target group of the site is big Internet service producers like Google or Facebook. Since they build massive scale data centers, the size of the site has to be enough big to enable also operator's future space requirements. Being close to the city center can also be important especially to colocation operators since most of the service clients are more likely to be physically there. Being close to the airport can also ease to attract international customers to use the data center service.

2.6.10 Advantages of increasing the size of data centers

Because this thesis focuses especially on the context of large data centers, it is important to identify the benefits of the consolidation of the data centers and discuss the advantages of large scale data centers compared to small data centers.

There has been an increasing demand for cloud computing applications. To answer for this development it is possible to make spatially distributed servers interacting together with high speed network. On the other hand, according to Parolini (2012 p. 6) there are at least three reasons why data-center-based solutions are preferable compared to spatially distributed server models:

1. It is easier to maintain a massive number of servers when they locate under the same roof. Managing the system in one physical location requires less people compared to distributed units.

2. With the collocated servers, the interconnection is possible with low delay and high bandwidth networks. When reducing the delay among the servers, the overall delay which end user faces is smaller and typically improves the overall quality of service.

3. When servers locate in the same site or area it is easier to guarantee the high level of data security and privacy. In addition to the software security, the site can be protected with physical barriers.

Greenberg et al. (2009 p. 68) have listed some characteristics that favor constructing big facilities instead of small ones with bigger distribution. Large scale enables for example smaller operational costs due to high automation and small amount of people operating the servers. Greenberg et al. (2009 p. 68) explain that in the big cloud service data center one person can be responsible for about 1000 servers when in the typical data center one IT staff member takes care of only about 100 servers. Another major advantage of the big scale are the purchasing prices for new servers (and other IT-equipment) which are logically lower when buying large quantities. Large cloud based data centers can also "scale out" meaning that the total workload is divided for the bigger amount of servers than in the enterprise data centers where the physical space often restricts the amount of IT equipment. "Scaling out"

enables to use less expensive servers and hardware to handle the workload which results in smaller acquisition costs.

Questions relating to the energy efficiency are also supporting the idea of increasing the size of data centers. Shehabi et al. (2011 p. 997) came to the result that the energy efficiency in large data centers is typically relatively better than in the small data centers. They also noticed that the difference in the energy efficiency became more significant when economizer solutions were utilized in the cooling (cooling efficiency was discussed in the Chapters 2.6.3 and 2.6.4).

Greenberg et al. (2009 p. 72) say that large scale can set also some difficulties. Finding a proper site for a large data center can be significantly harder than finding a site for a micro data center. Large data centers require big sites, but also local factors such as zoning, tax and power concession are playing a major role in determining where to locate a large data center. Greenberg et al. (2009 p. 72) say that there is significantly more freedom when choosing a location for a small data center.

2.7 Nordic data center market example: Finland

Since the restructuring development was already analyzed from the perspective of Finland, it was reasonable to use Finland also as an example country when analyzing the Nordic region as a potential destination for data centers. Despite the Nordic data center cluster is analyzed by using Finland as an example country, many of the characteristics typical for the Finnish data center market are similar in other Nordic countries.

2.7.1 Data center cluster in Finland

Nissilä et al. (2015 p. 9) say that there were about 2800 data centers in Finland in 2012. Most of those data centers are relatively small in size and only five of Finland's data centers consumed more than five megawatts of electricity, which is often considered the threshold for a large data center. In fact, large data center facilities can consume a lot more power than that. Nissilä et al. (2015 p. 2) narrate that especially large-scale data centers (Warehouse-Scale computers) have raised a great interest in Finland and set high hopes of getting those investments in Finland. Data center investments are also expected to boost the Finnish economy by bringing direct jobs and capital to the country. Data center investments have been also argued to speed up Finnish digitalization development.

Nissilä et al. (2015) continue that even Finnish government has been very enthusiastic of promoting data center investments and helping in creating the data center cluster to Finland. After Google invested in Hamina, there has been a growing ambition to lure other big Internet service and application producers to locate their data centers in Finland. According to Nissilä et al. (2015), that type of ambitions are not just positive thinking: Some regions have risen significantly their attractiveness after one "major player" has chosen to come to the region. After this so called "opening investment" other companies often realize the potential of the region and build their own data centers nearby the first comers. Nissilä et al. (2015) tell that described development has been realized especially in the U.S., but also in the Netherlands, where data center cluster has become a strong industry.

High hopes toward the data center industry in Finland are not just the fantasy of Finnish government and the data center cluster has been facing growth lately. Big Internet service

producers such as Yandex and Microsoft have already followed Google's example and built their data centers in Finland (see Rintakorpi 2014 and Nalbantoglu 2014). Also Finnish telecommunication operators have addressed interest toward building their new data centers in Finland. Sonera recently announced that it will construct its data center to Helsinki. The capacity of Sonera's data center will be at least 30 MW and it will be operational at the end of 2017 (Sonera 2015).

The Finnish data center cluster is not limited to just big data center operators and there are also few smaller data center operators for example in the colocation business. Also, some international colocation producers have found Finland as an interesting market and invested there in the recent years. For example Equinix/TelecityGroup has already total of 5 colocation data centers in Helsinki (Equinix/Telecity 2016). The most recent comer is German colocation operator Hetzner Online which announced its plan to open data center in Tuusula, Finland (see Salmela 2015; Finpro 2015). There are also several smaller colocation operators like Herman IT, Aiber Networks and Ficolo which run colocation business in Finland (Herman IT 2016; Aiber Networks 2016, Ficolo 2016). Also, Finnish telecommunication operators such as Sonera and Elisa are offering their data center services to the corporate clients (Sonera 2016; Elisa 2016).

The potential of Finland to host more data centers is notable. According to Invest in Finland there are 38 potential data center sites with more than 6 million m^2 of building rights and total power capacity of 1800 MW (situation in August 2015) (Invest in Finland 2015).

2.7.2 Characteristics of Finland as a location for data centers

Nissilä et al. (2015 p. 4) write that data centers require strong Internet connectivity, stable and well secured energy, favorable weather[19] and geography, stable political situation and transparent regulations (See chapter 2.6.5 for more information about data centers site selection). Most of those characteristics Nissilä et al. (2015) describe to be favorable for data centers are realized in Finland. The Data Centre Risk Index 2013 ranks Finland in the ninth place in the comparison of the data centers' macro locations[20]. (Data Centre Risk Index 2013).

The list of different factors is a combination of the important characteristics mentioned by Nissilä et al. (2015) and Spafford (2009). Each of the factors are discussed from the Finnish perspective.

Internet connectivity: Data centers need strong connections between the users and other data centers (Nissilä et al. 2015 p. 4). The Data Centre Risk Index 2013 ranked Finland for the 22nd place in the international bandwidth in 2013 (Data Centre Risk Index 2013). A new submarine cable from Finland to Germany will most likely improve Finland's position in the ranking at least with regards to the international bandwidth. Installing the submarine cable (C-Lion) started in October 2015 and ended after three months in January 2016. The new C-lion cable will be opened for the commercial use later in 2016 (Tivi 2016; Cinia 2016.)

[19] Chilly weather is considered at least as one of the desired characteristics for many data center operators.
[20] Macro location refers to different countries.

Energy: Reliable energy supply is essential for the data center's operations. According to Clipp et al. (2014 p. 30) at least 50 percent of the ongoing operational costs are coming from the use of energy. In Finland, the electricity prices are very competitive among other countries in Europe. According to Eurostat (2016b) "Energy price statistics", electricity price for the industrial consumers in Finland was the second cheapest in EU after Sweden (see Figure 16). In Finland, the electricity taxation for the data centers (bigger than 5 MW) was lowered in 2014 to the same level with other industries which have made Finland very competitive in terms of electricity price. (Finlex 2013; Artti 2015 p. 22).

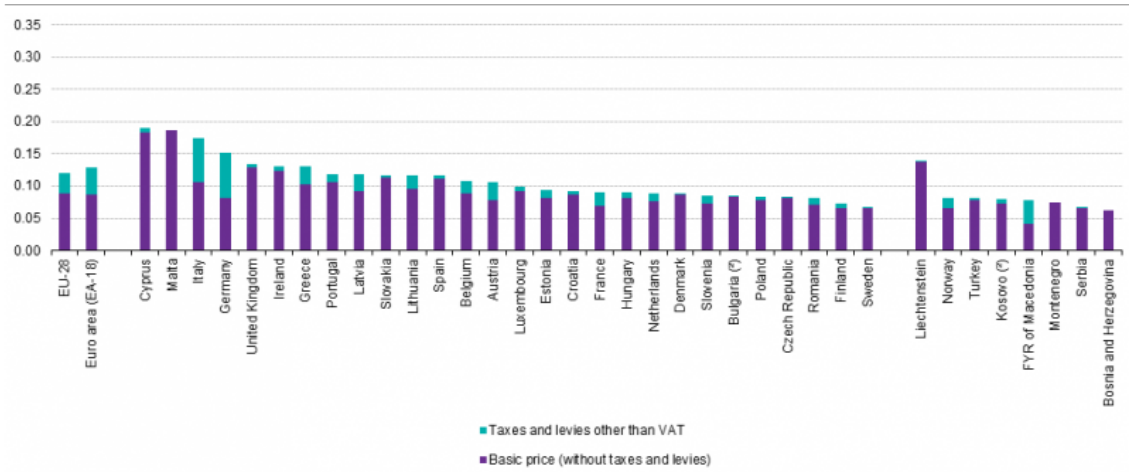

Figure 16: Electricity prices in Europe for the industrial consumers in the second half of 2014 (€/kWh) (Eurostat 2016b).

According to Fingrid (2016a) (*Finnish nation-wide high voltage grid operator*), transmission reliability in the Finnish national grid (Figure 17) was 99.99982 percent in 2015. This is considered as a very good level. The weakness of Finland in the energy matters is, that it is not self-sufficient with its energy production and about 70 percent of the total energy consumed is produced elsewhere (= imported energy) (Halme et al. 2014 p. 4). Finnish consulting and engineering company Pöyry (2015 p. 2, 26-29, 46) describes in their white paper that in terms of the electricity consumption Finland will be reliable of the imported energy also in the near future, even the situation will be eased significantly after the opening of the new nuclear plant Olkiluoto 3 in 2018. However, Finland has aimed to become more self-sufficient with its electricity sourcing in the 2020s (see Työ- ja Elinkeinoministeriö 2015b p. 11; Ministry of Employment and the Economy 2014 p. 23-25). Finland is also working to improve its renewable energy production and its aim has been to rise its wind power capacity to 2 500 Megavolt-amperes by 2020 (Fingrid 2015 p. 46).

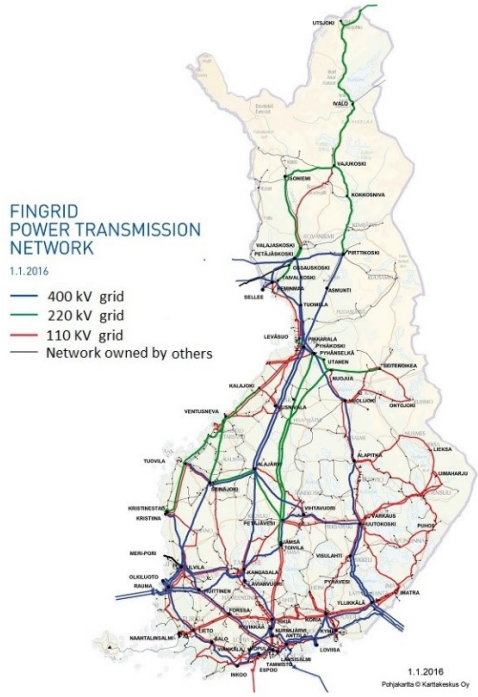

Figure 17: The Finnish national high-voltage electricity transmission grid (Main grid) (Fingrid 2016b).

Environment and climate: Finland is located in Northern Europe between latitudes 60 and 70 °N. Climate of Finland has characteristics of both maritime and continental climate. However, the mean temperature in Finland is seven degrees warmer than in other areas in the same latitudes, for example Siberia or South Greenland. In the warmest month, the mean temperature is no lower than 10 degrees Celsius and in the coldest month no higher than -3 degrees of Celsius (Finnish Meteorological Institute.) Chilly weather in Finland decreases the need for cooling in data centers and allows to use different free cooling solutions. (Advantages of a chilly climate: see Malkamäki et al. (2012) and Shehabi et al. 2010).

In Finland, the possibility for the natural disasters is small and Finland enjoys very solid bedrock. Data Centre Risk Index (2013) ranks Finland for the first place in the natural disaster category, which means that the risk of natural disaster was the lowest in Finland among 30 countries in the ranking.

Political environment and regulations: The political stability in Finland is high. Institute for Economics and Peace has ranked Finland for 6th place in their Global Peace Index (Global Peace Index 2015 p. 8). Another organization called Political Risk Services (PRS) ranks Finland in their Regional Political Risk Index 2015 for the fourth place (the fourth best score) in western Europe in terms of political risk (see Regional Political Risk Index (as of April 2015)). The corruption in Finland is also very low and in the latest Corruption Perception Index 2015 Finland placed second after Denmark (See Corruption Perception Index 2015). Nissilä et al. (2015 p. 6) say that Finland has also strong legal protection for the data which is beneficial for the data center business. Especially Nissilä et al. (2015 p. 6) consider Finnish data legislation being advantage compared to its neighbor Sweden.

Land and water availability: Finland is a sparsely populated country which enjoys plenty of free land. Invest in Finland (2015) has identified 38 potential sites for data centers (the amount of free sites, updated August 2015).

Modern data centers can use water for cooling as a primary cooling method or water can be used in the free cooling solutions to improve cooling efficiency. Finland has about 168 000 lakes bigger than 500 m^2 (Tilastokeskus 2014). There is also a possibility to use the seawater for cooling: Google is the first data center operator using seawater for server cooling in its data center in Hamina (Google Data Centers 2014).

Market size: Finland is a small country having relatively small home markets. Still, the Finnish economy is very export-oriented and big external markets in Russia and Central Europe are physically close.

2.7.3 Current and future project examples in Finland and other Nordic countries

SONERA, Finland
Sonera is planning to build its new data center to Pitäjänmäki, Helsinki. The data center of Sonera is going to be the biggest shared data center (colocation data center) in Finland. Sonera says that its new data center will offer cloud, colocation and "Internet of Things (IoT) aware capabilities" to businesses in Finland. The data center will be about 40 000 m^2 and its cost estimate is 130 to 150 million euro (STT info 2015; Smolaks 2015.) All the energy consumed in the Sonera's new data center will be produced with renewable sources and all the waste heat will be recycled (Smolaks 2015).

APPLE, Denmark
Apple announced in February 2015 that it is going to build its next data centers in Denmark and Ireland. Apple's investment will be total of 1.7 billion euro and consists of two new data centers. New data center facilities will host Apple's online services like App store, iTunes, iMessage, Maps and Siri. Apple says that both of the data centers will be powered with the 100 percent renewable energy. Apple has intentions to work with its local partners and develop additional energy projects in Denmark. The external heat from the Danish facility will be used for district heating to heat the neighboring homes and community. New data centers, each 166 000 m^2 are supposed to be operational in 2017 (Apple Press Info 2015.)

EcoDataCenter, Sweden
One of the most interesting data center projects in Nordic coutries is EcoDataCenter in Falun, Central Sweden. EcoDataCenter consists of three buildings with the total of 23 250 m^2 data center space. EcoDataCenter is said to be the first climate-positive data center in the world. Data centers use only renewable energy from several renewable energy sources (e.g. sun, wind, water and biofuels) and their excess heat will be used in the district heating. PUE of the facilities will be less than 1.15. Data centers have also LEED Platinum certificate (EcoDataCenter 2015.)

2.8 Nordic data center market examples: Hamina and Luleå

Two different Nordic data centers are presented as examples of the investments made in the Nordic countries. These two data centers are introduced since they have both been considered as success stories in the regional but also at the national level in both countries. Purpose of these data center examples is especially to clarify the background behind the investments and discuss shortly the reasons behind the companies' site selections.

2.8.1 Google's data center in Hamina, Finland

In 2009, Google[21] announced that it had purchased former Summa paper mill in Hamina, Finland and is going to build a big data center there. Prior the investment in Hamina Google had opened only one data centers in Europe.[22] Googles investment was great news for Hamina which was suffering from restructuring in the forest industry and a shutdown of Stora Enso's paper mill just one year before. In two years, Google transformed a 60-year-old paper mill into its modern data center (Nissilä et al. 2014 p. 12; Google Data Centers 2014.)

In the beginning, the investment of Google rose some suspiciousness but later it has become a success story for the region. The first phase of the data center began in 2009 and was worth a 200 million euro. Soon after the first phase ended, started the second phase in 2012 and was worth for 150 million. At the end of 2013 Google announced additional 450 million expansion, which raised the total investment in the data center facilities in Hamina for more than 800 million euro (Nissilä et al. 2014 p. 13; Kauppalehti 2013.) After the latest expansion Google's data center in Hamina becomes one of the biggest data centers in Europe (Kauppalehti 2013). Google has also future plans for expanding its capacity in Hamina even more and the new planning process is in progress (Yle Uutiset 2015a; Niemeläinen 2015).

Google tells that its data center in Hamina is one of its most efficient data centers. Data center is using sea water from the Bay of Finland for the cooling of servers. This kind of system was unique innovation and first of its kind in the world (Google Data Centers 2014.) Google tells that it chose to come to Hamina because of the unique and pre-existing infrastructure but also because an old paper mill offered "*the right combination of energy infrastructure, developable land and talented workforce for the data center*" (Google Data Centers 2014).

Nissilä et al. (2014 p. 13) write that according to Google, constructing the data center in Hamina has given in its peak work for total of 1800 workers and generated work for many in the supply chain. Running a data center employs also people daily. In the year 2014, 230 people were employed full time or in contractor roles in various tasks: engineering, technical work, security, food service, building and ground maintenance in the data center. Most of those people live in Hamina so they have significant impact on a local economy too (restaurants, cafes, bars, grocery stores etc.).

2.8.2 Facebook data center in Luleå, Sweden

Facebook[23] launched its first non-domestic data center in Luleå, Sweden in 2011. This data center is currently the only one of Facebook's data centers which locates outside the USA (Clipp et al. 2014 p. 12.) In the USA Facebook has at the moment three own data centers and construction of the forth one has begun (Facebook newsroom 2016). Facebooks data center in Luleå locates about 96 km south of Arctic Circle near the Luleå University of Technology (World Market Intelligence 2013 p. 5).

[21] Google Inc. is originally a search engine company which offers nowadays great variation of mainly internet related services.
[22] At the moment Google has 3 data centers in Europe (Google palvelinkeskukset_b).
[23] Facebook is a big internet company having world largest social network and the world most popular website Clipp et al. 2014 p. 5).

At the beginning of the history of Facebook it was leasing data center space, but soon it shifted to owning data centers. This development was the consequence of a huge growth of users but also because Facebook started to offer more applications and other content (Clipp et al. 2014).

Facebook's data center in Luleå is very energy efficient with the PUE of 1.09. The PUE value in Luleå is lower than in any other data center of Facebook thanks to cool location which minimizes the need for cooling. According to Clipp et al. (2014 p. 13), data center in Luleå runs only with the renewable energy from the hydroelectric station nearby. Renewable energy was one of the key factors why Facebook originally came to Luleå (see other factors from Chapter 2.6.5). The energy supply in northern Sweden is also very secure and there are plenty of cheap hydro and wind power (Kervinen 2015).

Now Facebook is constructing another data center in Lulea next to its current data center. The new data center is about the same size as the first one but due to technology development in the data center industry, the new data center should be more modern in terms of technical solutions (Kervinen 2015.) Facebook has argued that it chose that site and location to take an advantage of the chilly climate in the region and to decrease the need for cooling compared to warmer locations (World Market Intelligence. 2013 p. 5).

Clipp et al. (2014 p. 16-17) estimate that the positive effects of the data center of Facebook have been significant in Luleå. They estimate that during the first phase of the Facebook's data center in Luleå, the domestic spending were about 1.5 billion SEK most of the spending used for construction work. When all the phases of the data center are operational in 2018, the annual operating costs are estimated to be about 316 million SEK, most of that expenditures benefitting the Luleå region. Compared to the construction costs the operating costs are permanent and benefit the region yearly. In addition to the direct effects of the data center, there are also a lot of indirect effects on the local economy but also nationwide.

Clipp et al. (2014 p. 22) state in their white paper that there have been also some ripple effects after Facebook entered Luleå. The ICT sector for example has been growing since Facebook arrived to region and many new companies have opened their offices in the Luleå Science Park.

3 Empirical Research

In this section (part III) of the thesis, the research process is described and presented as an evolutionary process. In addition the basis for the interviews is introduced together with the main data collection method (thematic interviews). At the end of this section conducting the interviews are described and the interview sample presented and analyzed.

3.1 Research process

According to Hirsjärvi and Hurme (2006 p. 13), every thesis or study starts with the idea or a problem to be solved. That idea or research problem should at least have some existing theory where to construct new information.

The idea for this thesis pop-up in the discussions with Finnish-Swedish forestry company Stora Enso. In the beginning of the research process, the topic of the thesis was defined only as "Data centers" meaning that the definition for the thesis was very wide. The idea behind

the wide definition was to find an interesting viewpoint for the topic and then refine the idea forward. Since the topic was not strictly restricted in the beginning, enabled it to get familiar with the data center concept in general and take a look at the topic with the wide perspective. After getting familiar with the topic in general, the most interesting themes were chosen and actual research problems were designed and formulated among those themes. The scope for the thesis was also chosen by considering the previous know-how of the researcher.

During the first few weeks of the research process, ideas become more concrete and research problems got their shape. Basis for the research was found by getting familiar with the previous academic research about data centers but also by having vital conversation with the advisor of the thesis. In addition to academic research, also other data centers related articles were read in the industry magazines and other publications.

When carrying out the literature review, the fundamental information for being able to conduct the interviews was collected. Writing the literature review familiarized with the topic by many ways: Prepared for the interviews and improved the knowledge of the topic. Hirsjärvi et al. (2009 p. 164) argue that this kind of research strategy is typical for the qualitative research where original ideas are constantly improving during the research process.

When designing the interviews, many interesting themes were identified from the existing academic literature and previous studies. New themes were also discovered by having vital conversations with the advisor of the thesis but also with other data center professionals having hands on experience of the data center projects. Interesting themes for the interviews were also found by observing the data center market in Nordic countries by following different media (newspapers, TV, Internet (blogs, organizations reporting etc.). Observation was done mainly by following Finnish media but also other Nordic and international media were followed. The main themes for the interviews were chosen among many other interesting themes identified during the research process. Unfortunately, a lot of interesting themes had to be restricted outside thesis (see Chapter 6.4).

The research process is described in Figure 18. The whole research process from choosing the topic to writing the final sentences of the thesis took about seven months of intense work and one month of getting familiar with the topic and deepening the understanding of the topic. During the research process, a lot of new things were learned and many interesting people met (in the interviews). Research was conducted in the relatively linear process where new information was built for the basis of the previous knowledge. Research process might have been smoother if the researcher would have been familiar with the topic prior to the study.

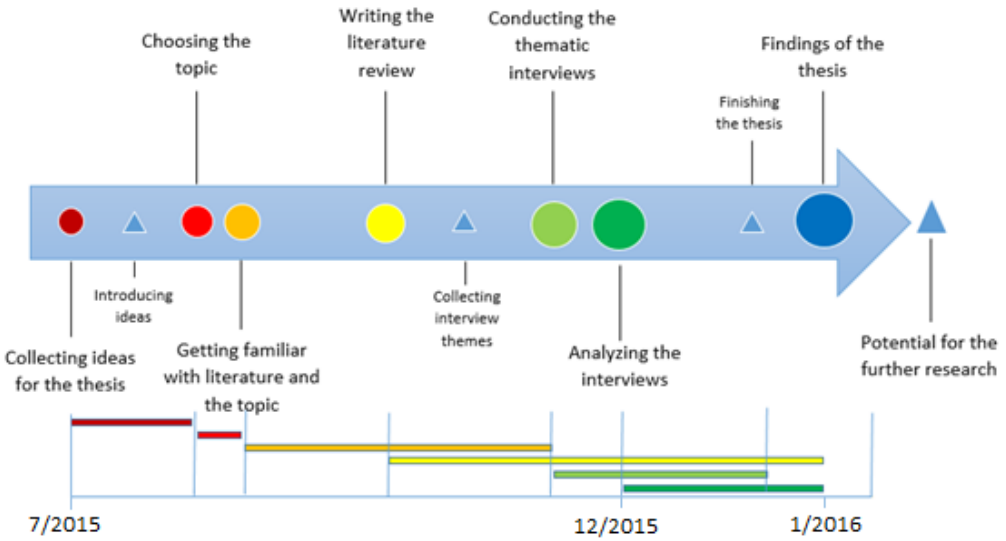

Figure 18: Research process shown as an evolutionary process. Circles are describing different phases of the thesis (Triangles are the steps that supported the process).

The research was done by using three different methods: literature review, observation and interviews, the main focus of the research being in the interviews. Other research methods were used to build the proper foundation for the interviews (main data collection method) and to prepare the conditions for conducting the interviews. In the thesis process, different phases overlapped with each other and were done side by side.

3.2 Interviews

Interviews are a flexible research method which fits many kinds of researches. According to Hirsjärvi and Hurme (2006 p. 43), the difference between different interview methods is basically a question of how structured are the questions. Fully structured interviews (formal interviews) form one own category and the rest of the interview methods (e.g. unstructured interview, semi-structured interview (thematic interview) and in-depth interview) belong to another category. Figure 19 shows different types of interviews and their characteristics.

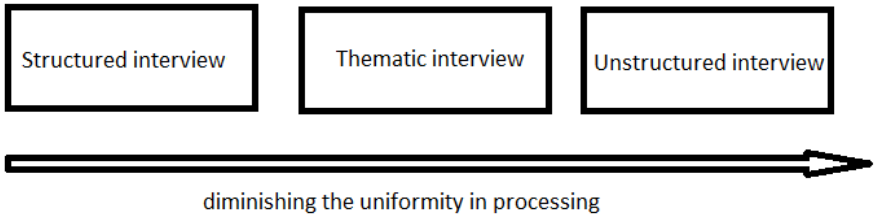

Figure 19: Different type of interviews compared to each other (picture modified from the original source Hirsjärvi and Hurme 2006 p. 44)

The main data collection method in the thesis was thematic interviews (often called also semi-structured interviews). Thematic interviews was chosen for the main research method since it was assumed to support the best the objectives set for the thesis. Since the researcher was not an expert in the field of study it was inevitable that some new ideas will arise during the interviews and it is beneficial if those ideas can then be used in the other interviews later. Also, by considering the fact that the written academic research comes often a bit late for the current situation in the industry, it was expected that in the literature review all the relevant

themes and ideas are not going to pop up. This is why any structured inquiry would not have fitted well for this thesis purposes.

Structured interviews were not taken into account for the same reasons (there would have been no possibility to modify the questions after starting the interviews). Semi-structured interviews (thematic interviews) were considered the most suitable method for the thesis purposes and data collection since method gives a lot of space for new ideas to occur during the research process. The interview method enables also free conversation during every interview, which at least gives a change for new ideas to be found. However, it was considered important to have at least some pre-planned structure and pre-made questions in the interviews for being able to guide interviews to the right direction and at least keep the conversation inside the chosen themes.

Hirsjärvi and Hurme (2006 p. 47) write that in the semi-structured interviews some aspects have already been decided but not every. Despite some of the questions can already be decided, has the researcher the right to modify them by changing the words or by formulating sentences with the different way. Thematic interviews are one of the semi-structured interviews methods concentrating on different interview themes. The themes of the interviews are for all the interviewees the same and interviews are carried out by following those themes. Themes are for the interviews more important than single questions so there is no matter how the interviewer decides to discuss them (= themes) in the interviews. However, thematic interviews differ from many other semi-structured interviews by not having the same questions or the structure of the questions for all the participants.

In this study, the questions were practically the same for all the participants. However, not every question was asked in every interview and questions were asked not word by word the same way in all the interviews. There were three main themes in the interviews and the interview questions were related to those themes. In many interviews, different themes were discussed very freely and "original" questions were kept in the background to remind the themes researcher was interested in. Still, sometimes the flow of the conversation in the interviews was not that smooth and questions had to be asked almost the way as they were written to keep the conversation alive. The general structure and the original questions of the interviews are presented in the Appendix 1.

With some of the interviewees there was also a need to compromise a bit with the original interview plan, questions and the interview structure. Not every of the interviewees had experience of all the interview themes and with a few of the interviewees the experience was quite limited which forced to make some compromises for their interviews. In those cases questions were modified during the interview and some of the themes were not taken care as deeply as was originally intended. In many cases it was possible to interpret the interviewee already during the first questions and adapt the course of the interview somewhat according to his/hers answers and target the interest toward those themes which the interviewee was the most familiar with.

3.3 Conducting the interviews

Conducting the interviews followed the original plan shown in Figure 20. First step was to choose the right people for the interview (see Chapter 3.4 Interview sample). The primary method for contacting the interviewees was email. Every participant was first contacted with email. If no reply to the first and second (reminder) email was received, interviewees were

contacted via phone. Total of 51 people or organization were preselected or found by snowball sampling (more about snowball sampling in the Chapter 3.4) for the interviews. 30 of those potential candidates were contacted and total of 20 people took part of the interviews meaning that 2/3 of the contacted people took part of the interviews. Unfortunately some of the desired people were not reached for the interviews (more about the problems of the study in the Chapter 6.1).

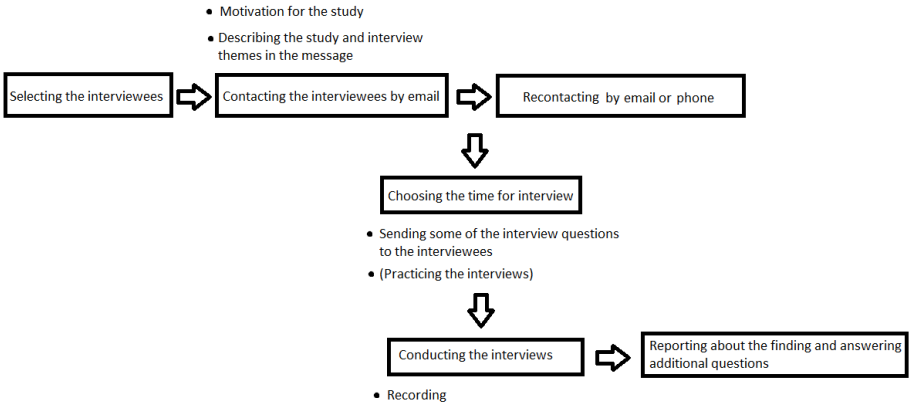

Figure 20: Interview process divided into different steps

Some of the interview questions (one to two questions per theme) were delivered to the participants beforehand after they had agreed for interviews and the day for the interview was decided. This was a strategic move that was hoped to encourage participants to be more prepared for the interviews and familiarize themselves in advice with the interview themes. However, there is also a risk of delivering or showing the questions beforehand for the interviewees: One can give predetermined answers representing more about the company's view about the themes, than interviewees. This kind of risk was considered relatively low compared to the possible benefits of having well prepared interviewees instead. However, not all the questions were delivered to keep the conversation free and get less prepared answers. Since no preparation was required, the result was that majority of the interviewees were not prepared for the interviews in any way.

All the interviews were recorded because all the interviewees had given a permission to do so. When contacting the interviewees, the general practices of the interviews were informed for the participants in the first contact email. The general practices of the interviews were also discussed at the beginning of each interview so that both parties were aware of the course of the interview and the general practices during the interview. Recording eased the following of the interviews and freed researcher's hands from making notes during the interviews. However, some notes were done during each of the interview to highlight some key words and to ease the later transcribing.

Duration of the interviews varied from 20 minutes to over 1.5 hours (see Appendix 2). Eleven (11) of the interviews were made face-to-face, seven (7) via phone or Skype and two (2) of the participants answered via email. All the interviews were done as individual interviews except one group interview. All the interviews were originally intended to conduct face-to-face if possible. Because some of the participants lived behind long distance or abroad (and the schedule for the research was tight and budget small), seven (7) of the interviews were conducted by using phone or Skype. All the interviews[24] were transcribed

[24] One interview was not written word for word since the quality of the recording was bad (See Chapter 6.2).

word for word from the recorded material. This transcribing process took a lot of time (average of 6 hours intensive work per interview) and resulted in around 61 400 words of written material. Transcribed material was not delivered for the participants since it was not considered important.[25] However, if some of the interviewees had been interested in seeing the transcribed material of his/hers, it would have been possible.

Before conducting the interviews, different interview strategies were studied from the literature, but also some experiences of other students were exploited. Two training interviews were conducted before the first actual interview and the structure of the interviews was modified based on those training interviews.

3.4 Interview sample

Because this thesis concentrates on the data center possibilities mainly in old industrial sites (brownfields), the thematic interviews (semi-structured interviews) were targeted to the instances, people and organizations having previous experience on similar data center projects. The experience of the brownfield projects was not a necessity for the selected interviewees, but it was considered as an advantage. On the other hand it was essential to avoid choosing interviewees from too similar backgrounds and so avoid too homogenous results. All the 20 interviewees had at least 1.5 years experience of the data center business. The knowledge areas of interviewees are shown in the Table 3.

Table 3: Interviewees divided according to their expertise and organization.

EXPERTISE	(ORGANIZATION)	AMOUNT OF INTERVIEWEES
Site manager	(Single owner/Enterprise DC)	1
Consultant	(data centers/IT, business, investing)	3
Data center expert	(Invest in organization)	2
Various roles	(Colocation DC)	3
Various roles	(Regional Development company)	7
Various roles	(City/municipality)	4

The interviewees were chosen by considering that they represent various organizations (e.g. cities/municipalities, colocations operators, enterprise data center operators, consultants etc.) to construct so called “big picture” of the data center industry. Common for all the interviewees was that they all had personal experience of different data center projects or they had been closely connected with the data center projects in their current or previous profession. The biggest interest in the interviews was to concentrate on large data center investments in the old industrial site (brownfield) environment. That intention was kept in mind when selecting the participants for the interviews. Since there have been only a few large scale data center investments (e.g. Google, Facebook and Yandex) in the Nordic countries, most of the interviewees were chosen from the interest groups of those projects.

Most of the interviewees came from Finland (15) but interviewees from Sweden (4) and Iceland (1) were also interviewed. People from Denmark and Norway were also contacted but unfortunately those contact requests did not lead to any interviews. *Invest in organizations*[26] of different Nordic countries were always the first ones contacted and to

[25] If the citations had been shown in the thesis by identifying the person behind the citations with the full name and the name of the company, it would have been reasonable to deliver the transcribed material to participants before using the citation in the thesis.

[26] In Sweden same type of organization is called Business Sweden.

open conversation about the possible interviews. This was planned approach since invest in organizations have maybe the best knowledge of the previous and forthcoming businesses in the country including data center investments. Because of the tight schedule and restricted budget for the research, all the interviews outside Finland were conducted via Skype or telephone. Nevertheless, this was a bit unfortunate since face to face interviews turned out to be often more fertile with the Finnish interviewees.[27] Interviews with Finnish interviewees were held in Finnish and interviews with Swedish and Icelandic participants in English.

Even the sample of the interviewees was selected beforehand (*non-random sample*), the sample of the interviewed people was more random. One third of the people being originally intended to take part of interviews was not willing or able to participate in the interviews. Unfortunately, some of the pre-selected interviewees were not even reached during the interviews despite many tries. Especially some large data center operators were not willing to give information about their operations or share their previous experiences to the research purposes. In a few cases, no one even answered back for the contact requests despite organizations were contacted multiple times with different ways such as email, telephone or even social media.

Most of the participants represent either city/municipality or regional development company type of organization. Those organizations are a bit over-represented in comparison with the original plan (where intention was to get especially more interviewees from the data center operators). However, especially participants from the regional development companies had been in a close contact with the data center operators during organizations site selection processes and the knowhow of theirs was generally extremely strong – which made them ideal participants for the interview. Despite the non-randomly chosen sample (of people), the interview sample can be considered quite diverse as can be seen from Table 4.

In the selection of the interviewees the "snowball sampling" was used. Hirsjärvi and Hurme (2006 p. 59) explain that snowball sampling means basically that researcher identifies some key people from the field of study. By interviewing those key people, researcher gets the first touch to the topic. After their interviews, the researcher asks them (= interviewees) to suggest other interviewees who could have additional information or who they know to have useful information about the research theme. This same procedure is repeated until new names are no more coming or interviewees are repeating the names being already interviewed. Metsämuuronen (2006 p. 53) describes that with the snowball sampling researcher can catch up those individuals or people who are hard to find other way. Snowball sampling is also a useful method when the research topic is somehow sensitive – information is not available for everyone (due to national security etc.) or research group does not want to be recognized (e.g. criminals or drug dealers).

In this thesis "snowball sampling" was used to support the pre-selected list of data center professionals. Especially snowball sampling worked with the first interview participant and with finding data center professionals elsewhere than Finland. Most of the Finnish experts had already been identified before starting to conduct interviews and snowball sampling brought very few new names. Therefore snowball sampling was used only with the first Finnish interviewees and with the interviewees from other Nordic countries.

[27] This was highly dependent on the interviewee. Nevertheless, interview type did not play a major role in the interviews.

Table 4: The list of interviewees

	COUNTRY	TITLE	(RELEVANT) KNOWLEDGE AREA
DEVELOPMENT COMPANY			
1	FINLAND	Marketing Director	Marketing, Investments
2	FINLAND	Business Advisor	Investments, Real Estate
3	FINLAND	Key Account Manager	Data centers
4	FINLAND	CEO I	Data centers, Real Estate, Business
5	FINLAND	CEO II	Business development, Investments
6	SWEDEN	Development Director	Real Estate Investments
7	SWEDEN	Investment & Development Director	Real Estate Investments
CITY			
8	SWEDEN	Business Development Director	Real Estate Investments, Business Development
9	FINLAND	Senior Real Estate Advisor	Data centers, IT-business, Real Estate
10	FINLAND	City Manager	City Development, Data centers
11	FINLAND	City Manager	City Development
CONSULTANT			
12	FINLAND	Senior Consultant	IT, Business Development, Real Estate
13	FINLAND	Managing Director	IT, Data centers, Fiber networks
14	SWEDEN	Consultant	IT, Technoly development
DATA CENTER EXPERT			
15	FINLAND	Site Manager (Enterprise)	IT, Data centers, Real Estate
16	FINLAND	Site Manager (Colocation)	IT, Data centers
17	FINLAND	Operations Director	IT-business, Networks, Real Estate
18	FINLAND	CEO	Real Estate, Colocation,
INVEST IN			
19	FINLAND	Head of Industry	Data centers, Investments
20	ICELAND	Project Manager	Business development, Investments, Data centers

At the beginning of the interviews there was an idea of interviewing at least few data center industry experts from every Nordic country to get a perspective of the data center industry in each of the Nordic countries. Since no interviewees from Norway and Denmark took part of the interviews, interviews concentrated naturally more on analyzing the data center market in Finland and Sweden (from where most of the interviewees came from and had the best expertise). However, other Nordic countries were not consciously ignored, but due to the interview sample the role of Finland and Sweden is pronounced in the results (validity and reliability of the interview sample are discussed in Chapter 6.3.1).

4 Analysis and findings

In this section (part IV) the analysis of the thematic interviews is presented. At the beginning of this section, the methods for analyzing the findings are presented and the way they were used in the analysis, described.

The analysis of the findings of thematic interviews is divided into three main themes:
Theme 1: Old industrial sites in the data center use
Theme 2: Data center investments in the Nordic countries and
Theme 3: Data center trends.

The findings of each theme are presented separately. At the end of each theme or subtheme there is a table which summarizes the main findings.

4.1 How the material was analyzed

The first step in analyzing the interviews was to transcribe all the recorded interviews.[28] In addition to the recorded material, also the written notes (made during the interviews) were transcribed. The length of the recorded interviews varied from 20 minutes to 1.5 hours, meaning that the longest transcribed interview consisted of 14 A4-pages while the shortest just 3 A4-pages. The difference in the length of these two different interviews was a consequence of two different kind of interview strategies. In the shortest interview only one interview theme was gone through (interviewee had promised to answer only one of the interview themes) when the longest interview consisted also a lot of free discussion in addition to the interview themes.

After all the interviews had been transcribed, the actual analysis was conducted. Two different methods were used in the analyzing. First and the priority method was to classify the answers of the interviewees under different themes and headings. This kind of analyzing method is called thematizing. Headings were such as *brownfields, greenfields, how to boost brownfield investments* and *ways to attract foreign investments* just to name a few. This kind of classifying was important because often interviews were not conducted in the chronological order and answers to the different themes were all over the transcribed material. Classifying different answers under different themes and headings helped also to find similarities from the answers and to find possible citations. The citations used in the analysis and discussion of this thesis are direct citations of the interviewees. However, the citations of Finnish interviewees are in fact translations from Finnish to English since interviews with Finnish participants were all held in Finnish. Translations were, nevertheless, made the way that not just the idea of the original citation was maintained but also by pointing great attention toward the used words and the style of the original citation.[29]

Another method used in analyzing was quantification. Saaranen-Kauppinen and Puusniekka (2006a) say that quantification helps to find some countable elements from the qualitative material. Quantification eases also to find the main themes and ideas from the transcribed material by presenting them in a countable form. Quantification fits well to qualitative research since it helps the researcher not just to present findings in a countable form but also to improve the certainty that findings are not just based on the vision or the feeling of the researcher. In this thesis, quantification was used to support thematizing and to find the key elements from the transcribed interview material. Tables after each interview theme are based on the results of quantification. Quantification was done in English.

Saaranen-Kauppinen and Puusniekka (2006b) say that thematizing and quantification are analyzing methods which can be used together in analyzing the material. The Researcher had also used both of these methods in his previous course works and was familiar with the use of both methods. Those were the primary reasons why the use of thematizing and quantification were natural analyzing methods also in analyzing the interviews in this thesis.

[28] Naturally, transcribing was made with the same language as the actual interview.

[29] Translations can be considered being very close to the original citations. The comments of interviewees were not polished during the translation and all sentences were kept very similar to originals (even the word order) if it was possible within the grammar rules of different languages.

4.2 Interview themes and the findings of the interviews

There were three main themes in the interviews which were discussed with the interviewees. The first of these themes was *the use of old industrial sites in the data center use*. This theme was the leading and the most important theme in the research and got the biggest attention both in the literature review and thematic interviews. This theme had not attracted big interest among other researchers before which was one of the reasons why it was chosen to be the leading theme and getting the greatest interest in this thesis.

The second theme in the interviews was to *find ways how to attract data center investments to Nordic countries* and also learn *to identify the advantages and disadvantages of Nordic countries considering data center industry*. The main focus in the interviews was to learn from the previous experiences of the data center investment and try to identify what kind of actions have brought investment to countries. Interesting was also to identify differences between Nordic countries and if those different characteristics have been affecting on the realized data center investments. One of the interests was to identify how data center investments have been promoted in Nordic countries and what have been the results of those actions and if there is something to improve in the future for being able to lure more data center investments to countries.

The third theme in the interviews was to find the trends of data center industry. This theme is very significant by considering the potential of Nordic countries to attract data center investment in the future. Knowing the data center industry and its possible development and being able to identify future trends is one of the key issues if Nordic countries want to attract new data center investments in the future.

Interviews focused on discussing those three different themes in the large data center context. This means that the size of the data centers investments discussed was several megawatts (e.g. 5-100 MW) and the value of the investment multiple millions although no precise definition for the data center size was used.

4.3 Theme 1: Old industrial sites in the data center use

In this interview study, brownfield sites were defined as the following way (direct citation from the interview paper, see Appendix 1):

"In this research Brownfield sites mean old industrial sites with no contamination or contamination is very light. Existing buildings are in a good shape, with no need for major renovations (i.e. old paper mills)"

The definition for brownfields used in the interviews was formulated only for this thesis purposes and it is not any official definition of any instance. Modified definition for brownfields was used to restrict the use of term "brownfield" to mean typical old industrial site environment in Nordic countries. The purpose of using different definition for brownfields was especially to ignore those brownfield sites which need a lot of expensive alterative work before the new future use.

4.3.1 Choosing a site for a data center

Choosing a site for a data center is an important if not the most essential decision for the data center operator. In the interviews, the goal was to understand why most of the large data

center investments in the Nordic countries have been made for the greenfield sites instead of the brownfields.

According to the interviewees, the main advantage of the greenfield sites is the possibility *to bring own data center concept without compromises*. This means that bringing data center technology into the brownfield environment forces investor(s) always to make some compromises in the design of the data center. There can be for example a lot of pillars or the building can be some other way hard to use in the data center use. Many big data center operators also prefer to duplicate their data center facilities all over the world. In practice this means that when they (= data center operators) have created a functional model for data center design (i.e. how data center looks like and how functions are organized), they build similar facilities all over the world and only modify building slightly to meet the local conditions. For brownfield environment this kind of design is often impossible to be implemented and, especially if old buildings are going to be harnessed, the design of the data center has to be made for every facility individually. This idea was summarized in the interviews for example by the following ways:

> *"You can make greenfield exact for your demands. When you build on old building, you have to rebuild it somehow. New building is probably more energy efficient and effective."*
> *-Investment Consultant, SE*

> *"Some of the data center operators want to build their data center to certain shape. For example one operator built a data center in the shape of an airplane wing. This you can't do in the old industrial building."*
> *-CEO I, Regional Development Company, FI*

> *"Greenfield sets no restrictions how you use the space or how you build your business environment."*
> *-Senior Consultant, FI*

Compromises with the brownfield buildings can mean that the space cannot be used as efficient as if the building would be new. Many interviewees underlined that the value of the existing building is relatively small compared to the total costs of a data center. Servers and IT equipment together with the cooling and electricity systems are the main cost factors in the data centers. Compared to those three elements, the building itself is not a big source of costs. This is one reason why "old walls and roof" (read: buildings) are not considered as a big cost advantage. Common opinion among interviewees was that the existing buildings are often seen as a too challenging and risky. It is often easier to keep the business simple and start from the clean table in the greenfield environment. Brownfields were often seen also as too big risks for the core business and economically expensive solutions. With the greenfields, you "know what they get" when in the brownfield environment there is always a greater risk that something unexpected pops out. Generally, greenfields were also seen as more economical solutions than brownfields even few opposite statements were stated (e.g. the third citation).

> *"Constructing data center in the brownfield environment is way more expensive, especially if the structure of the building needs modifications. Some kind of a warehouse building could be ok if the space is large enough and open.-- Often we are not achieving any cost saving, quite the contrary."*
> *-Enterprise Site Manager, FI*

"We had here a long list of about 20 sites from which about 10 were old industrial sites [brownfields]. [In Brownfields] the infrastructure was always somehow inadequate or integrating the cooling solution would have caused more costs than building the whole facility from the clean table. The calculations showed that starting from the clean table in the greenfield is economically more justified. Of course zero euro is always an attractive price."
-Managing Director, Consultancy Company, FI

"We know the Finnish but especially the local infrastructure the way that we have been able to do fast decision to use existing infrastructure and buildings plus other commodity infrastructure. This has meant -- b) very cost-efficient approach."
-CEO, Colocation Data center operator, FI

Many of the interviewees mentioned that one reason why investors often choose greenfields is also their better availability (the number of available greenfield sites is often way greater than brownfields). One practical example which supports this vision was mentioned by many Finnish interviewees: Invest in Finland has in its lists mainly greenfield sites and only very few brownfields. [30]

However, even greenfields were often seen more potential and suitable for the data center business purposes, some interviewees also highlighted the potential of brownfields. In the interviews became clear that when harnessing a brownfield site to new purpose it is essential to know the environment well. By knowing the environment investors are able to take full advantage of the existing environment and maximize its potential. For example many interviewees highlighted the existing potential of old industrial sites and their good condition in the Nordic countries. Brownfields were also said to have great potential for many other type of future uses than just data centers. For the data center use, the existing electricity and cooling infrastructures can often be harnessed quite easily and there is no need for constructing those functions completely from scratch.

One positive element of brownfield sites was the possibility to speed up the whole process from the design to construction when the existing environment can be used without any major modifications. For example in the old paper mill environments the fast overall process was seen as a potential scenario since the need for new wiring for electricity and arranging cooling solution can be drastically reduced due to already existing solutions used in the previous business.

"The reason why investors are interested in old industrial sites is that they have useful infrastructure which helps and speeds up the construction process. If you have for example big power supplies on site, it is an advantage. These facilities [data centers] are using lots of electricity and if you have to bring it to the site it can take even years."
-Sales Director, Regional Development Company, FI

[30] In fact Invest in Finland has 45 potential sites for data centers from which 40 have been classified as greenfields and 10 brownfields (5 of the sites consists of both greenfield and brownfield). (Invest in Finland 2016)

Positive aspect with the brownfields is often the site environment. Especially in the old industrial environments security of the sites has been important also for the previous owner and new security solutions for the site can be arranged based on the former security infrastructure. Brownfields are also often located in the convenient locations for businesses such as data centers – close to people, clients[31] and potential workers in the forthcoming data center. It is possible that greenfields with the same kind of characteristics and with such central location are not available or they are too small or expensive for the large data center facilities. In the interviews became clear that finding good location for the data center can be extremely difficult especially in the bigger cities. Even in the Nordic countries the availability of free greenfield sites can be very limited in the urban environment and brownfield sites can be the only available sites in the city structure. Being in the city structure can enable many positive things like using the excess heat of data center in the district heating, finding workers close to site or being close to the clients just to name a few.

> *"Brownfield is excellent if it is located in the" right place" and the excess heat can be used for heating the neighborhood. This rises the value of brownfield [in the city structure] versus greenfield in the forest. Being relatively close to city center is good for being able to connect it [data center] with district heating."*
> *-Enterprise Site Manager, FI*

> *"The intention is to locate data centers there where the customers are or at least close to them."*
> *-Enterprise Site Manager, FI*

One interesting aspect in the comparison between greenfields and brownfields was the carbon footprint. Few of the interviewees underlined that the importance of environmental issues has recently risen and is more likely to increase in the future. Due to that trend the use of brownfield sites can rise its importance. By using the old environment, carbon footprint often stays lower than with the new buildings which also brightens the public image of the data center operator or other brownfield user.

> *"What is important for the company? Is it the cost or the image? For the companies it is a matter of image that they found old industrial building and reused it. It cost a bit more, but they did it. If we only think about the money…so [it does not make sense]."*
> *-Enterprise Site Manager, FI*

For Table 5 is listed different factors found in the interviews which favor choosing either greenfield or brownfield site. Different classes are based on the following classification:

Class I: The most important factors:	≥ 40 percent of the interviewees considered as benefit
Class II: Important factors:	≥ 25 percent of the interviewees considered as benefit
Class III: Other reasons:	≥ 10 percent of the interviewees considered as benefit

One should note that classification is based on the prevalence of different benefits of choosing either greenfield or brownfield. Interviewees were not asked to list different reasons for choosing brownfield or greenfield in any order of their importance. Even the

[31] The proximity of clients is especially important for colocation operators.

advantage is listed to *Class III: Other reasons* it does not necessarily mean that it is less important in the site selection than other listed factors. Classification indicates especially what majority of interviewees considered being important for choosing certain type of site.

Table 5: Comparison of greenfield and brownfield sites. Listed factors are different reasons which interviewees considered important for investors for choosing either greenfield or brownfield site for their data center. More economical solution means that the total cost of constructing a new facility (sales price of the site plus construction costs) is smaller.

	Greenfield	Brownfield
class I: The most important factors	• Possibility to bring own concept/no need for compromises • The value of existing buildings is small compared to other costs (so by using old building no cost savings are achieved) • More economical solution*	• Advantages of the existing infrastructure
Class II: Important factors	• Better availability of sites • Easier to use/More simple designing • Smaller risk/Knowing what you get	• Excess heat and cooling solutions • Faster overall process • Often central locations
Class III: Other reasons	• Easier to grow with the business • Often easier to arrange security issues • Old industrial building are not optimum for data centers	• Smaller carbon footprint/more ecological solution • More economical solution (if high use of existing infrastructure)*

4.3.2 Boosting data center investments in the brownfield environment

> *"It is terrible to think that many of the old industrial sites are without new users. Of course we have to find ways to find them new use."*
> *-CEO I, Regional Development Company, FI*

Previous comment describes the fact that new uses for brownfield sites should be found to make those environments lively again. In addition, to understand the logic behind the data center investments and why operators choose to come either to brownfield or greenfield environment (see the previous Chapter). There was an intention in the interviews to find data center industry professional's opinions about how brownfield sites could be turned into attractive for the investors and how to grow the interest toward them. In the interviews, many different factors were found to boost brownfield investments.

The key factor which most of the interviewees mentioned was that investors should be better informed about the available brownfield sites and their characteristics for being able to understand their full potential. One interesting finding was that often the owner knows the site well and is aware of its potential, but this information is not delivered with the right way to the potential investors. Site owner can even have specific information about the needed modifications for being able to start running data center type of business in that special

environment. This information is however not necessarily delivered to the potential investor since certain things can be seen too obvious or they are ignored as irrelevant. Although some things might seem very obvious from the owner's point of the view (who has possibly experience of running the business in the site for years), they might be fundamentally important information for the investor.

> *"We have excellent strengths in the brownfield environment [this case old paper mill], but those are for us too obvious and we are not able to tell them to the clients by simple enough. Maybe we should think of those strengths from the client's point of view. We know the environment but telling the right way about it to the client seems to be a bit hard. Maybe we assume that when we know it [the environment], others know it too."*
> *-CEO, Colocation Data center operator, FI*

Marketing of the brownfields has also been suffering from the "one size fits all" kind of thinking meaning that same sites have been promoted for very different kind of client with the same sales arguments. "One size fits all" type of marketing was considered as one of the biggest mistakes in the current site marketing.

> *"We have to understand client needs. With one size fits all thinking we lost clients for sure."*
> *-Key Account Manager, Regional Development Company, FI*

Many of the interviewees said that there is still a lot of to do with the marketing of both greenfield and brownfield sites for data center use. In many of the interviews, the idea of more targeted marketing popped out as an idea for turning marketing more efficient. More targeted marketing can mean for example that the sales organization identifies the potential clients (investors) and construct its marketing material and strategy based on those key clients instead of just having the same marketing strategy and material for all the clients.

One idea of the interviewees was also to broaden the amount of clients by taking into account many kinds of clients. The target group for brownfield sites should not be just the big Internet service producers constructing data centers for their own use (enterprise data centers) but also domestic and international colocation service producers should be seen as potential clients. Especially if the site is located in the urban environment, it is more likely that colocation operators are interested in it because being close to clients is usually important for their business. Interviewees had the following kind of approach to the idea.

> *"It is important to clarify for yourself, what kind of business is global cloud business and which kind of needs they [data center operators] have. As important is to understand the needs of colocation service producers constructing data center space for other users to rent. The demands of these different business models are way different considering the infrastructure and location. This difference everyone should clarify to themselves. Important is to know who you want to offer the site."*
> *-Senior Consultant, FI*

> *"If we are not considering other than those huge operators as potential clients, we are kind of not thinking who really are those clients having intentions to invest in brownfields. By concentrating only on big operators we will lose [potential] clients."*
> *-Key Account Manager, Regional Development Company, FI*

Especially Finnish interviewees had noticed that brownfields have been promoted mostly for the very large data center operators (meaning e.g. Internet service producers). This might not be the right strategy especially when there is a growing demand for new sites among smaller data center operators. Target group for brownfield sites can be as well operators running a few MW data centers, not just operators building huge complexes. Interviewees discussed also about some positive examples of colocation operators who have built their data centers in the brownfield sites. These companies should be used as references. Still, when speaking about the paper mill sized brownfields, the primary target group is most likely large data center operators especially in case there is an intention of finding an operator to purchase or rent the whole property. [32]

> *"My vision is that we should choose our client again and concentrate on small operators in the size of 1 to 2 MW. There is the money and there are plenty of those players. -- Then we can fill all boundary conditions and criteria.*
> *--Colocation solutions fit well to old paper mills."*
> *-CEO I, Regional Development Company, FI*

> *"From the owner's point of view operators building data center space for others are more potential in the brownfield environment than operators constructing a data center to their own use. We should focus on the marketing to the companies like TelecityGroup [=colocation operator]. There are plenty of that kind of operators in the world. They are capable of doing modular solution and are doing relatively big investments. We have in Finland some [Finnish] companies in the colocation business. The challenge with them is that we are speaking about relatively big investments and those companies might need an anchor company for being able to proceed with this kind of projects."*
> *-Key Account Manager, Regional Development Company, FI*

A big problem is also that investors might not understand that some of the industrial sites can be quite easily modified for the data center use and even some cost savings can be achieved with rational planning. Some of the Finnish interviewees said that in Finland for example many paper mills have been built in the places being very ideal for the critical businesses such as heavy industry or data centers. Those paper mills are often placed in the nodes of the electricity grid and the electricity infrastructure can be harnessed quite easily if the building is modified to the data center use. In addition, those old paper mills are often built next to big water reserves such as lakes or rivers which can be exploited in the data center cooling if needed.

Existing infrastructure also brings other benefits for establishing a data center. Many data center operators often search for a fast start for the business. Investment decisions are maybe not always made in the fast tempo but when the investment decision is made, constructing should start soon and data center be operational in a short time frame. Some interviewees discussed that especially this hectic approach toward the business makes brownfields competitive among the greenfields where getting all the required permits for being able to start constructing a data center can take a long time. According to interviews, by taking advantage of the existing constructions and especially the existing infrastructure (such as electricity and cooling infrastructure) makes possible to have time savings in the construction process and be able to establish the business in a fast tempo. Some of the

[32] There is always a possibility that site can be shared with many smaller operators. However, dividing sites into many pieces is maybe not the most desired option for the owner.

interviewees state that especially permit processes with the power grid can be in some cases extremely time-consuming.

> *"The reason why someone gets interested in these type of old buildings [old industrial sites] is that there is a lot of external infrastructure, which serves and speeds up the process of coming there. If there are for example big power supplies, [it is a great advantage since] these data centers are using a lot of electricity. If you have to build and bring those power supplies, it may take many years to get sufficient links to the site."*
> *-Sales Director, Regional Development Company, FI*

As mentioned already in the previous Chapter 4.3.1 location of the brownfields can bring some benefits. City environments, often desired among data center operators, often suffer from the lack of free land. Big cities are often already built-up and not much free greenfield land exists. Especially when speaking about the data centers in the size of multiple MW the need for space can be counted in hectares. This means that free greenfields in the urban structure are often way too small for large data centers. Some of the interviewees underlined that data centers are usually build by considering also the future growth, not just the current need for space. This statement was explained by the fact that data centers are usually build in many phases and investors are looking for sites which have enough space for their needs also in the future.

> *"There should be enough place for a data center to grow in the brownfield. In the ideal situation, the company can grow inside the walls [of the building] and buy more land from the surroundings in the future."*
> *-Business Advisor, Regional Development Company, FI*

Due to restructuring, some integral city functions (e.g. harbors, railroads, factories and electric power plants) have been freed from the central locations. Those sites could be ideal locations also for data centers in case they offer enough strong electricity and fiber network. A problem with the locations of that kind is often that cities have to think, what could be the "highest and best use". This means that cities have to consider what functions produce the highest value for the property. In those speculations data centers might lose competition with offices or residential buildings at least in the areas where the demand for those functions is high together with high land value. [33]

> *"If there is a good hall in the city, we have to solve, what kind of purposes it suits the best. New use can be for example a hardware store, sports hall or data center. Some locations can be even too good for data center…if the hall is next to a metro station, it is maybe too good location for a data center. These are the things that we have to consider."*
> *-Senior Real Estate Advisor, City, FI*

One of the innovative approaches in the interviews was the idea of placing data centers in the places where residential buildings or offices have less potential or are forbidden. Those kinds of locations are for example caves and other underground spaces. Data centers could be located also for areas with the high noise pollution rates being not suitable for residential buildings.

[33] Offices typically generate more workplaces per m^2 than data centers. Land value and demand is typically high in the city centers. Such things as sea view or close metroline can increase the land value. In Helsinki for example beachfronts are often addressed for the residential buildings.

"Noise impact areas where you cannot place other functions are good [for data centers]. However, next to the airport or harbor it is maybe not safe enough for data center."
-Senior Real Estate Advisor, City, FI

Another advantage of brownfield sites comes via central location. Brownfields have been integral part of the urban structure and been possibly connected also to the district heating. If data center is built in that kind of place, it can be used to produce district heating for the city heating network or at least the excess heat of data centers IT equipment can be used for the heating of residential buildings or offices next to the data center. Common opinion among the interviewees was that if brownfields wants to be competitive with greenfields there has to be "something unique". This unique "thing" is, however, not "the walls and roof", it has to be something else. For example all the applications of using the excess heat can be those unique elements which make brownfields interesting among investors.

"To have an old industry hall with the basic structure is not the thing. You have to have something unique which opens the eyes of investors."
-Managing Director, Consultancy Company, FI

One important element when speaking about brownfields is their image. In the interviews, some interviewees mentioned that brownfields might still have slightly bad image among some investors. However, many interviewees said that the common opinion of brownfields at least in Nordic countries is not very negative. Still, for being able to enhance the image of brownfield sites to more positive was seen as one possible way of boosting brownfield investments.

"The added value in the brownfield operations is the image. There are two positive things: Firstly we are using the old and recycling the environment and secondly we are a responsible operator when we reuse the old."
-City Manager, Small city, FI

To reuse old industrial sites can be seen as positive action also toward the nature and environment which also minimizes the carbon emissions since the need for new buildings disappears or at least decreases. Sometimes by reusing the old constructions it is also possible to achieve some economic savings (discussed in the previous chapter 4.3.1). So by using the brownfield site for one's business does not necessarily have to be only polishing the public image of the company and the use can be based on the economic considerations.

However, the basis for promoting data center investments in the brownfield environment is, that the conditions and quality of the brownfield sites are good. If the environment is dirty, contaminated or other way forbidding, finding an investor is more likely to be impossible or at least very hard. In the ideal situation previous owner has left the place in a good condition and taken away their own belongings. [34]

"[Brownfield] property should be clean and tidied up. All the additional staff should be removed and the environment should be like "sterile box" where data center technology can be brought to."
-Head of Industry, Invest In, FI

Different ways for boosting data center investment in brownfield environment are summarized in Figure 21.

[34] The definition for brownfields in this thesis was underlining the same thing. See Chapter 4.3.1.

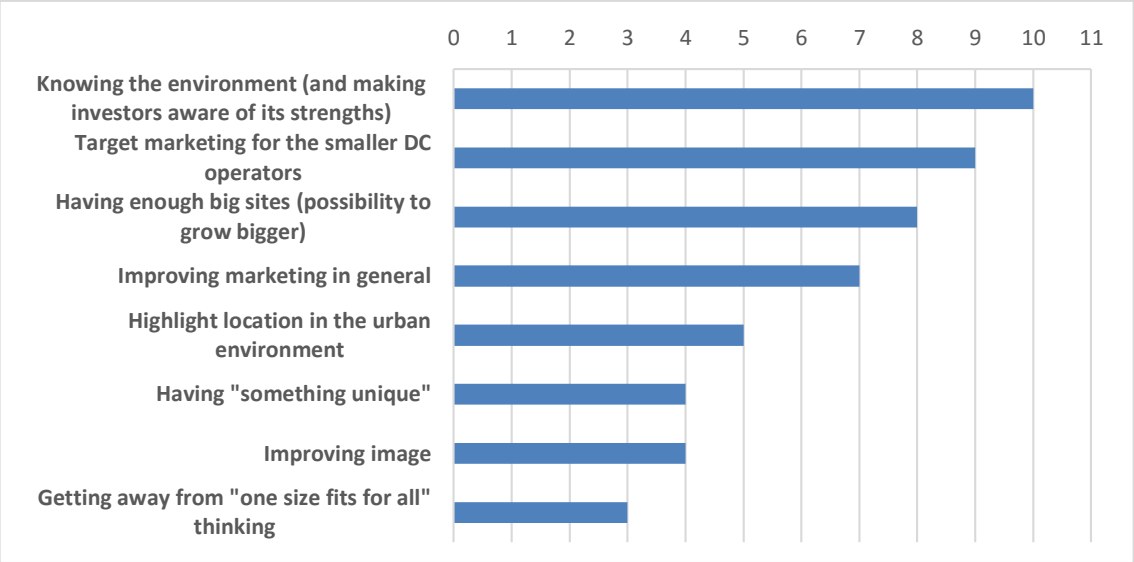

Figure 21: Ways for boosting data center investments in the brownfields. Numerical values describe how many of the interviewees suggested certain alternatives as potential ways to boost data center investments in brownfields.

4.4 Theme 2: Data center investments in the Nordic countries

The Second theme of the interviews concentrated on three issues: *Finding ways to attract foreign investments to Nordic, identifying Nordic advantages/disadvantages* and *making some comparison between Nordic countries.*

Attracting foreign investments:
One of the main questions in the interviews was: How Nordic countries could improve their position in the race of foreign data center investments? In the discussions with the interviews the current situation of data center industry was analyzed in the whole Nordic context but also the effort of each country were discussed separately. Since most of the interviewees came from Finland, the Finnish role in the findings might be somewhat over-represented.

Nordic advantages/disadvantages:
It is commonly known that Nordic countries have some advantages (e.g. cold weather and green energy) which are making region a desired destination for data centers. In the interviews, the advantages but also the disadvantages of Nordic countries were first identified and then analyzed. The Nordic region was treated in the interviews as one single market. Still, some typical characteristics of each country are underlined in the findings to note that countries also have some differences. Treating Nordic countries as one single market for data center investors was seen as a natural approach also among many interviewees. [35]

> *"We need to accept and realize that all new investments in Nordics are great for everyone, whether it takes place in Helsinki, Stockholm or in The Node Pole. We compete when all of course want to have investments with them. But we will win in the long run by speaking good about each other and helping each other when possible. When Nordics grows, it will be a benefit for everyone."*
> *-Chief Commercial Officer, Regional Development Company, SE*

[35] Some of the interviewees note that international data center operators often see Nordic countries as one market.

Comparison between Nordic countries
In the interviews, some typical characteristics of each country were identified. However, comparison was made especially to help to understand differences between countries and how they might affect on data center investments.

4.4.1 Ways to attract foreign investments to Nordic countries

According to interviews, the common opinion was that the demand for data centers is more likely to grow in the future (was noted also in the literature review). The rise of the interest toward data center industry has been growing also among Nordic countries in the resent years. This development has been caused by some of the large data center investments in the Nordic countries. Many interviewees mentioned that they have noticed that the biggest interest toward the Nordic region begun after Google purchased an old paper mill in Hamina in 2009 and started to run data center there. Now Google's data center in Hamina is one of the biggest data centers in Europe (Google's investment in Hamina was introduced in the chapter 2.8.1). Sweden got its "big fish" in the year 2011 when Facebook decided to open its first European data center in Luleå, in Northern Sweden. After those two investments the interest toward data center industry has been growing significantly in all Nordic countries and the potential of the region has been admitted.

One of the questions in the thematic interviews was presented in the following way:
How Nordic countries can get their share of the future data center investments?
One of the interviewees commented this question as follows:

> *"This is not any small question, it is sixty-four-thousand-dollar question."*
> *- Sales Director, Regional Development Company. FI*

Interviewees found many ways to improve the Nordic countries status in the competition of getting data center investments in the future. Certain themes were discussed almost in every interview such as *the role of Invest in organizations*, *the need for fast fiber optic networks* and *having well organized marketing organizations* just to name a few of the topics which got a lot of attention in the interviews.

The role of the *Invest in* (in Sweden: Business Sweden) organizations was seen as one of the key factors for getting data center investment to Nordic countries. Many interviewees underlined that these state-owned investment organizations are often playing a central role in the promotion of the countries. They are also taking part in different events and fairs and promoting the investment possibilities for the potential foreign investors.

> *"When investor gets interested in Finland, it is natural, that they found us with the help of Invest in Finland organization."*
> *-Sales Director, Regional Development Company, FI*

Foreign investors are often taking the first contact to the country by contacting Invest in organization and informing about their interest toward the country. After this contact Invest in organization begins to search potential sites considering the investor's needs. [36]

> *"The role of Invest in Finland is important, but not the only channel where we found possible investors."*
> *- Sales Director, Regional Development Company, FI*

[36] Still, it should be noted that different data center operators have different investment strategies and the site selection process can be proceeded not only in the co-operation with Invest in organization.

Another element which interviewees considered very important for getting new investments to Nordic countries was *better marketing* (as with the brownfield sites). Especially Finnish interviewees had common opinion that marketing efforts of the country (meaning especially Invest in organization) and different site owners (e.g. cities/municipalities and private owners) would need improvements. Many Finnish interviewees underlined that according to their observations Sweden has been the most active player in the Nordic data center scene and promoted their possibilities the most visible. Nevertheless, Swedish interviewees were not seeing any major differences between their own marketing and marketing of other Nordic countries.

Many Finnish interviewees had a common point of view that in the future data center marketing should be more client-oriented than currently. Common opinion was that marketing should be more targeted to the desired customers (similar idea than with the brownfields, see Chapter 4.3.2). Some of the interviewees were also pointing out that currently there is too little amount of differentiation in the marketing efforts even the variation of different kind of sites is big and the needs of different data center operators far from each other. There are also practical examples of this king of marketing behave: Many sites are promoted for all kind of data center operators with the same sales arguments even the needs of colocation and single-owner (enterprise) data center operators are often very different.[37]

> *"Some of the greenfields, brownfields and colocations have been dropped to the same basket, which is even according to this conversation [wrong]. -- So improving the possibility to differentiate [is important]."*
> *-Key Account Manager, Regional Development Company, FI*

The common opinion of many interviewees especially in Finland was that, the marketing should answer more to the client's needs, not just show which kind of resources are available. Some of the interviewees were underlining that marketing should be in the future more proactive and possible investors should be met in person but also by taking part in the different conferences, industry events and fairs to get new contacts and rise the interest toward own data center possibilities.

> *"We can list our resources to the end of the world but if the buyer [the investor] does not know what to do with them it does not make any sense. If we can offer them solution to get added value to their business, they will listen."*
> *-Senior Consultant, FI*

One often noted issue in the interviews was that the competition of getting data center investments have become significantly fiercer in the past few years. This development has happened also in the Nordic countries.

> *"At the moment it is no more enough just to have a site with the proper planning. Requirements for the data center sites have risen significantly in the past few years. The level of commercialization when starting to sell or market data center sites has to be very high."*
> *-Managing Director, Consultancy Company, FI*

Interviewees emphasized that the marketing should be active and the quality of the sites high to rise client's interest. The planning process for the sites should also be fast since investors are often in a hurry when it comes to their investment decisions but also with the construction

[37] Colocation operators for example need multiple fiber optic communications from many telecommunication operators when single operated data centers can be operated with much smaller amount of connections.

time. Many of the interviewees highlighted, that in fact the planning of the site should already be done or at least in progress before even starting to market the site. Some of the interviewees underlined that marketing should be done if possible with *talented teams and people* who are able to answer investors' questions in a short time frame. Many of the Finnish and Swedish interviewees raised up The Nord Pole (the consortium of four municipalities in northern Sweden) as a good example of the successful marketing.

> *"If you start planning at the phase when you have met the possible investor, it is often too late since planning might last a year with all the appeal processes etc. You have to have a suitable site and environment already ready for the investor – it is a requirement if you want to get data centers. To have only some sites to offer is not enough. You have to have something more complete."*
> *- Sales Director, Regional Development Company, FI*

Fast planning is important since investors are often in a hurry and want to spare total time of investment (from the purchase to operating) by searching sites with already prepared conditions for data center or other similar facility. Relatively small things like harvesting and leveling the site can be important at least to visualize the place for the facility. Some prepared investment calculations (i.e. how much costs an investment of 5 MW or 10 MW size data center in the region) can ease investors to estimate the costs of constructing or operating data center in the region.

> *"[Leveling and harvesting the site] is not a big cost, but it eases to visualize.--If a client comes here, it is easy to see that there has been built [a data center] and there is a field where I (I refers to the client) could build one versus there would be a forest. It is kind of building an image and vision for it."*
> *-Site Manager, Enterprise data center, FI*

It is important to take care of the other circumstances in addition to the physical aspects of the site. Some of the interviewees highlighted the importance of *collecting all important parties together*. Collecting all important parties together means that negotiations of the data center investment are not held just between the site owner and the investor since there are a lot of other relevant issues to be solved in addition to just having a proper site. It is a great benefit for the investor if someone helps to coordinate the project and collects important stakeholders together for investment negotiations. This kind of link between the owner and the investor is often regional development company or the municipality.[38] In the investment negotiation important stakeholders in addition to trade partners are for example fiber optic network operators, energy companies and municipality officials.

> *"We have been able to collect all the parties around the same table. Then data center operator does not have to hunt different parties high and low and the process goes smoother and faster. I found this very important [approach]."*
> *-CEO I, Regional Development Company, FI*

Many of the interviewees found the importance of *earlier references* very important for attracting new investments. For example if a big Internet service producer (e.g. Google, Facebook and Twitter) has chosen country and the region for their data center, it will certainly rise the attentions toward the market area (e.g. Nordic countries), country (e.g. Finland) and the region (e.g. eastern Finland). Many interviewees found that many of those earlier references have not been exploited enough good and some of their potential has been wasted by not taking the full use of them in the promotion. Some of the interviewees

[38] In the large investments Invest in organization and different consultants are often used.

proposed that sales/investment organizations should take data center operators with them to the industry events to tell about their experiences of operating data center in the country and region. Interviewees considered the experiences of data center operators extremely interesting to other data center operators (potential investors) since only data center operators can have hands-on experience of operating data center in the country and region. Many of the interviewee hoped to see that kind co-operation more in the future.

However, some Nordic countries have already realized the potential of earlier references. Invest in Iceland for example has taken advantage of country's earlier data center references by arranging conferences and industry events where data center operators being already in Iceland have been introducing their experiences of running data center(s) in the country. People from those data center companies have been also invited for the international fairs and industry events to represent Iceland together with the Invest in organization.

> *"When we go to the exhibitions, we try to have some of each stakeholders to be part of the booth. We are then able to answer all the questions with right manner. Then if we have a speaker slot, we try to get someone from the companies that have located in Iceland to tell their story."*
> *-Project manager, Invest in, IS*

In the interviews was stated that there is potential to improve that kind of co-operations. Unused potential could lie in the "small" domestic data center operators who have good understanding and knowhow of the data center possibilities on the certain market.

> *"We should show that we are doing this business. --We should tell everyone how we are doing business here and thereby enhance our credibility."*
> *-CEO, Colocation Data center operator, FI*

Some of the interviewees from Finland were hoping to see more *co-operation between municipalities* in the future. By working alone municipalities often have very limited resources to make promotion especially when it comes to promoting the region internationally. By combining the resources of e.g. a few close municipalities there could be better possibilities to do the promotion which could benefit everyone.

> *"We should increase co-operation in this industry. We have too many small players like we are. What people know about [name of the city] in the world? Helsinki is maybe the only city [in Finland] which people know abroad."*
> *-CEO I, Regional Development Company, FI*

Some of the interviewees were also hoping to see more information shared between different players in the industry and more co-operation between different actors.

> *"I think that the basic information between different actors should be shared. It means such thinks like: What investments require? What has to be taken into account etc.? This kind of information should be available and delivered for everyone [who is interested in getting data centers]."*
> *-Key Account Manager, Regional Development Company, FI*

One way for improving Nordic countries position in the competition of investments is of course *improving the overall circumstances* in Nordic countries. This means for example *fiber optic network improvements*, lowering or having moderate energy prices compared with rival countries in the future, having moderate energy taxation for data centers and improving the quality of sites just to mention a few of the potential sources of improvements

found in the interviews. Cheap electricity is especially a key factor for investors. Electricity prices have been relatively cheap in the Nordic countries compared with other European countries, which has been one of the key strengths of Nordic countries. Interviewees found that this advantage is essential to be kept in the future if Nordic countries want to attract more data center investments.

> *"Because 60 to 70 percent of the data center operative costs are caused by the electricity use, every percent which is possible to spare there or get cheaper is [away from] the total cost of ownership."*
> *-Enterprise Site Manager, FI*

Governments in the Nordic countries have noticed the potential of the data center industry for creating new foreign investment. Some of the interviewees underlined that this can be seen for example in the *energy taxation* for data centers which has already been lowered in Finland[39] and tax reductions are planned also in Sweden and Norway (see Nikel 2015). Many interviewees found those kind of actions very positive signs from the governments' side showing that data centers are much desired and their potential has been identified.

One important factor in attracting investors is *the quality of the potential data center sites*. Sites should be high class to compete among other regions in Europe. According to interviewees if countries can offer sites with a strong and reliable energy network, good fiber optic connections and skilled workforce available within a close distance, the package starts to be interesting among data center operators. Then operators only have to find those sites among many. For being able to be seen, site owners should have many channels to show what they have to offer. One of the channels should be *Invest in organization* but in addition there should be also other channels.

Many interviewees underlined that data center business is similar to other businesses and selling data center sites is *typical sales work* where the winning combinations are often combinations of successful marketing, excellent conditions and something unique which turn the investor's interest. Many interviewees said that in the future this unique angle could be ecosystem solutions (more about ecosystem solutions in the Chapter 4.5).

Figure 22 summarizes the findings of the interviews about the ways for attracting foreign investments in Nordic countries.

[39] Also Denmark has lowered tax rates for qualified users (see Clipp et al. 2014 p. 27).

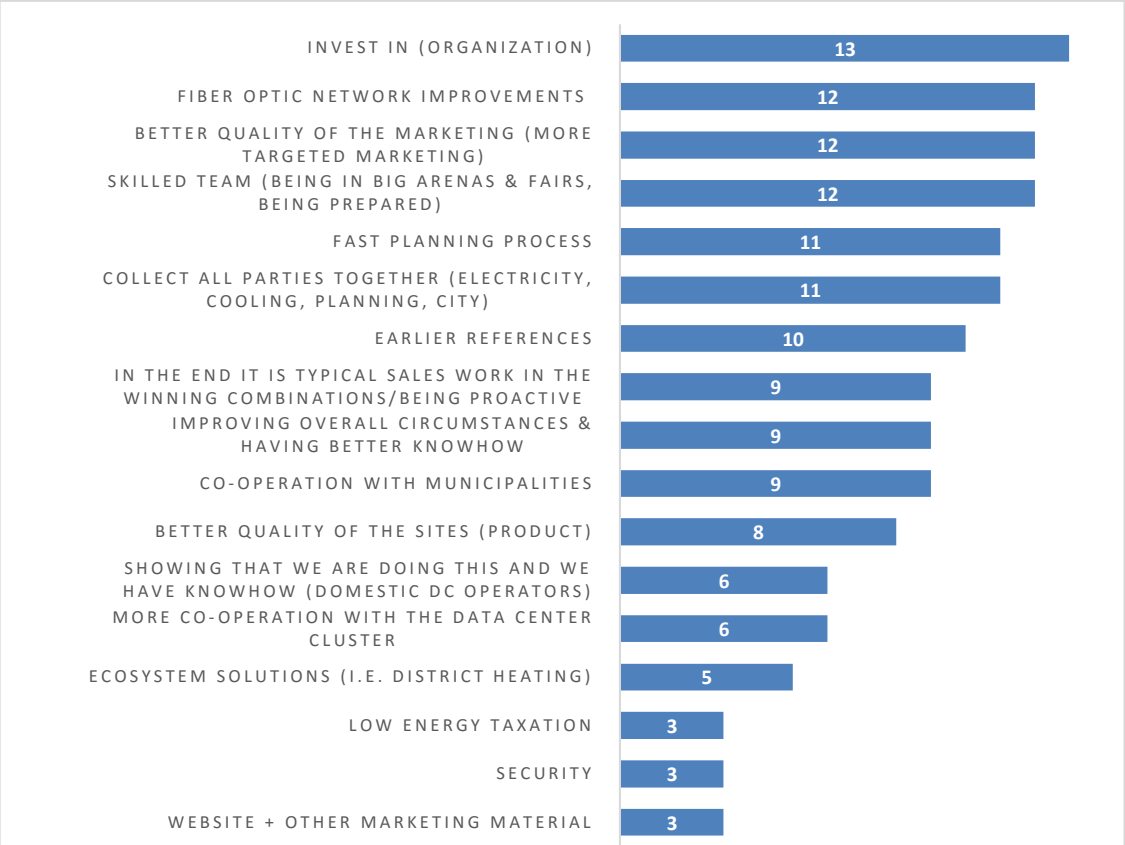

Figure 22: Ways for attracting foreign investments to Nordic countries. Numerical values describe how many of the interviewees mentioned the idea in the interviews.

4.4.2 Advantages and disadvantages of Nordic countries

The advantages and the disadvantages of the Nordic countries identified in the interviews are divided into three main categories:

- *Big advantages/disadvantages*
- *Moderate advantages/disadvantages*
- Advantages having only *small influence.*

Advantages and disadvantages were divided into three different categories based on the interviewees' opinion of their importance but also by considering how many of the interviewees mentioned them as advantages or disadvantages. Some of the advantages were considered as game changers.[40]

4.4.2.1 Nordic advantages

Big advantages
The big advantages of Nordic countries were according to interviews followings:

- Free cooling possibility (chilly climate)
- Good Political stability and security in the region
- Cheap energy (electricity)
- Being overall economical solution for data centers (cheap operating costs)

[40] A game changer is an advantage which stands out from the other advantages and is often the key reason behind the investment decision. However, game changers are not necessarily important to all investors.

Many of the interviewees found chilly climate and the possibility to use *free cooling* all year long as an important advantage of Nordic countries. Since the whole region is located in the same climate zone all of the countries offer data centers relatively similar potential to use free cooling solutions. Some of the interviewees considered chilly climate as a major advantage when some of the interviewees considered that the importance is nowadays relatively small due to improved server technology. However, most of the interviewees found free cooling possibility as an existing advantage of the Nordic region which is also used often as one of the sales arguments. The importance of chilly temperature has, nevertheless, become smaller due to server technology development which has made possible to run data centers in the higher temperatures. Some of the interviewees were even forecasting that the advantage of the cool climate enabling the use of free cooling can disappear in the future when the technology allows even hotter temperatures for data center operating.

> *"We think that it is cost-efficient to locate a data center to [cold locations]."*
> *-CEO, Colocation Data center operator, FI*

> *"The cooling process is a major cost component, but we can be certain that innovations and technology development increases – the need for cooling the servers will decline in the future."*
> *-Chief Commercial Officer, Regional Development Company, SE*

Political stability and security in general was considered as a great advantage of all Nordic countries. Legislation of the Nordic countries and especially its predictability was considered as an advantage. Many of the interviewees were also pointing out that doing business in Nordic countries is well secured and safe in comparison to many other regions.

> *"[Answer for the question, what are the advantages of Nordic countries]. We have stable and safe political situation in Nordic."*
> *-Site Manager, Colocation, FI*

Energy prices are playing a big role in the data center investments since most of the operating expenses come from the use of electricity. Electricity prices in the Nordic countries have been cheap in comparison with other countries in Europe (see Eurostat 2016b). *Cheap energy prices* were considered as one of the most important advantages of Nordic countries. The price of the electricity consist of three elements: the selling price of the electricity, the transfer price and the electricity tax. Electricity prices for all the countries in Nordic (except Iceland) are determined according to Nord Pool spot price. This spot price is the same across Nordic countries. Still, the electricity prices for the consumers are not the same in Nordic countries due to different transfer fees and electricity taxation in the countries (see Nord Pool 2016).

> *"The price of the electricity is the most important for the operators. In Finland, the electricity price is very competitive in comparison with Central Europe even when we think about the price in the long run."*
> *- Sales Director, Regional Development Company, FI*

Many interviewees had the opinion that operating the data center in the Nordic countries is cheaper than in the other countries in Europe which is also considered as one of the biggest advantages of the Nordic countries. To have *the cheapest data center operating cost* can also be a game changer which helps Nordic countries to win the competition of new data center investments against other regions.

"Almost no matter how you count it is cheaper to operate data center operations in the Nordics."
-Chief Commercial Officer, Regional Development Company, SE

"The reason why some international operator builds a data center here in Finland or other Nordic countries is that it is somehow much more economical than elsewhere. Otherwise coming to this periphery does not make sense."
-Senior Consultant, FI

Moderate advantages:
The moderate advantages of Nordic countries according to interviews were:

- Availability of district heating
- Green energy sources
- Stable electricity grid
- Highly skilled workers
- Fiber optic networks

District heating is commonly used in the Nordic countries. Especially important district heating is in Finland, Sweden, Denmark and Iceland where district heating is the most important source of space heating. However, in Norway district heating has only very little importance (See for more information about the district heating in Nordic: Denmark and Norway: Wikipedia contributors 2016c; Sweden: Ericsson 2009; Finland: Energiateollisuus ry 2014). Interviewees found district heating availability as an advantage since data centers can be integrated as part of the district heating. This can produce big economic benefits for the data center operators when they are able to sell the excess heat generated in the IT equipment instead of just releasing it to the outside air. This kind of business logic works extremely well in Nordic countries where district heating is the most commonly used source of heating (except Norway).

A good example of harnessing data center for district heating production is the city of Mäntsälä in Finland. Mäntsälä uses the excess heat of the Yandex data center to heat apartments and commercial buildings in the city. Yandex data center was often mentioned in the interviews as a positive example of Nordic potential in terms of using the excess heat of data centers. Similar applications in the smaller scale are also used in the other places in Nordic countries.

"The advantage in Finland is that we have district heating network almost in every a bit bigger city or population center."
-Head of Industry, Invest In, FI

Green energy solutions are excellent selling argument for Nordic countries. Interviewees pointed out that the energy in the Nordic countries is very green compared to many other countries and the basis of the energy production is based on the renewables. This was considered as an important issue especially since the importance of green values is rising internationally. Already some of the international data center operators (e.g. Google) have "zero carbon footprint policy" which rises the position of Nordic among those operators due to good green energy potential (see Google green). In the interviews green energy was considered as a game changer in case two different locations are similar in other respects.

Many interviewees considered *stable electricity grid* and *reliable energy supply* very important for data centers. Especially Finnish interviewees were underlining highly reliable electricity grid of the country being great advantage (transmission reliability in Finland was described in Chapter 2.7.2).

> *"Our national energy grid is very reliable. Even it has been already in the conversations with the investors, it should be highlighted in the future even more."*
> *-CEO, Colocation Data center operator, FI*

> *"Our downtime in the electricity [in Sweden] is almost nothing. It is very good. Operating data center with no downtime should be easy to be done here."*
> *-Business Development Director, City, SE*

Highly skilled workers in the countries were also seen as an important factor to lure technology companies like data center operators to the countries. Nordic countries have a reputation of highly developed countries having lots of high tech expertise. This kind of reputation has been achieved especially by being first countries to adapt mobile technologies and Internet solutions but also by having leading technology companies in the mobile and network sectors. Many of the professionals in those industries could be potential workers in the data centers especially when the unemployment in the mobile sector has raised due to increased international competition.[41] Some of the interviewees found that also the know-how from the process industries (for example forest and metal industries) could be utilized in the data center industry processes.

> *"We have know-how from the heavy industry in Finland which could be utilized in the data center business. --We have strong industrial know-how. Data center business is critical but the processes are very simple compared to heavy industries in Finland."*
> *-CEO, Colocation Data center operator, FI*

An important factor for the data center operators are of course the *fiber optic connections*. Generally Nordic countries have very good inner fiber optic networks. Fiber optic network improvements can turn more attention of the potential investors toward the countries and also show international operators that countries are taking fiber optic network improvements seriously. During the research, the installation of new sea cable from Finland to Germany was in progress. New submarine cable improves the fiber optic network of all Nordic countries but is especially important to Finland. The new undersea cable is important for Finland since it shortens the latency between Finland and Central Europe but also gives Finland for the first time straight, uninterrupted connection to Central Europe. Many of the interviewees underlined that good fiber optic connections and network improvements are important for all Nordic countries.

> *"Finland and other Nordic countries have very strong fiber optic networks compared to many [other] countries. It is one reasons why big operators want to [be] in Nordic countries."*
> *-CEO I, Regional Development Company, FI*

[41] Especially Finland has been suffering from the decline of Nokia. Later Microsoft has also decreased functions in the country.

Advantages with small influence:

- *Being* close to Russia
- Security of data
- Stable bedrock and stable natural conditions
- Clean air

Being *close to Russia* can be important for some of the data center operators. Russia has big domestic markets and a lot of potential customers for data center services. However, the political contradictions and sanctions between Russia and western countries (especially EU and the U.S.) have caused some uncertainty for running the business in the country. Some of the interviewees were seeing current situation as an advantage to Nordic countries since they can offer data center operators close location to Russian market for not actually being in Russia. Nordic countries can also be good locations for Russian data center operators if they want to take first step for spreading their business to other countries in Europe.

> *"Being close to Russia is an advantage which should be mentioned. It will be a great advantage in the future if it is not already."*
> *-Key Account Manager, Regional Development Company, FI*

Security of data is important for the data center operators but especially for the clients of their (=operators) services. The legislation for data security in the Nordic varies between countries. Sweden has been openly admitting that they monitor the data which is transmitted through the country. In the interviews, the security of the data centers in the Nordic countries was considered good or excellent in comparison with the other countries in Europe (see also Chapter 2.7.2).

> *"This [data center business] is not risk seeking business so they [operators] always want to have security as number one."*
> *-Project manager, Invest in, IS*

Stable bedrock and stable natural conditions are important for all the critical businesses like data centers. The bedrock of Nordic countries is relatively stable (despite Iceland) and the risk for natural disasters is low compared to many other regions. Interviewees were considering this stability as quite generic advantage which is an advantage but not the key reasons why some operators would invest in Nordic countries. Some of the interviewees were also mentioning that the clean air in the Nordic cities is advantage if the free air cooling solutions are utilized. Clean cooling air reduces the need for changing the filters in the cooling systems and thus reduces the costs and need for cooling system maintenance.

> *"When we decided to use air cooling, the site was chosen by considering the air quality of the place. We need a lot of clean air. The cleaner the air is the better for us because we blow lot of air through our data center."*
> *-Enterprise Site Manager, FI*

4.4.2.2 Nordic disadvantages

Big disadvantages:

- Small domestic market

Relatively *small domestic market* in the Nordic countries was considered as a big disadvantage for businesses needing big domestic market. In the data center industry, these kind of business models include colocation and latency critical enterprise (single owner) data

centers in the finance and banking sector. For the cloud service producers, the market size in the data center locations is often not a critical factor since clients of the services can be served from a distance. For the colocation operators market size is important since most of the service users (= clients) want their data (or IT equipment) to locate physically close despite their business would not be any latency critical etc. The biggest data center hubs in Europe are located in the financial centers and large metropolises like London, Paris, and Amsterdam (more information in Chapter 2.6.7). Often small data centers are build close to clients or users but operators building large facilities are often searching places where they can spare in the operating costs.

> *"If we think about the colocation operators, I have a personal vision that at the end of the day most of those international colocation operators are going to place their data centers close to metropolitan areas. They want to be sure that the distance for the big population is [going to be small]."*
> *-Managing Director, Consultancy Company, FI*

Moderate disadvantages:

- Latency
- Expensive operating of data center (expensive telecommunication costs)
- Bad image

Latency is often related to the market size. Clients of the data centers want their data and servers to locate there where their offices or other functions are or at least being relatively close. Also, some of the services are latency critical such as several banking and finance services. However, most of the other data center services can be managed from the long-distance and they are not very latency critical. Still, according to interviews latencies are very important to the data center operators and operators are measuring them continuously. This does not, however, mean that data centers placed in Nordic countries would not be able to serve clients in the Central Europe in terms of the accepted latencies.

> *"Practically the idea is that operators coming to Northern Europe and especially to Finland are searching for large sites. This means that the scale which they are going to implement is often massive, meaning tens of megawatts. –They are not usually interested in bringing a low latency facility with a few megawatts this far."*

> *"If you want to run cloud business, it is often not that latency critical. It is reasonable to have two to three bigger facilities in each continent."*
> *-Managing Director, Consultancy Company, FI .*

Operating costs are important for all the data center operators. The energy is the main source of the operating costs in data centers. Even electricity in the Nordic countries is cheaper than in the most of Europe, the total operating cost of data center can become higher in Nordic countries than when operating data center closer to clients in Central Europe for example. Especially telecommunication costs increase when data has to travel long distances to the clients. This is why the total costs of operating data center in Nordic countries can rise higher compared to the data center which is operated close to users.

> *"Some of the companies have chosen to go to Central Europe. They have gone there because they are closer to their core customers there. We can have cheaper operating costs here [in Nordic countries] but the quality of the service and telecommunication costs become cheaper there [in Central Europe]. The total cost of investment is cheaper there."*
> *-Operations Director, Colocation, FI*

"Even the electricity is cheaper here, more expensive telecommunication costs are a bit weakening that advantage."
-Key Account Manager, Regional Development Company, FI

One of the findings in the interviews was that the image of Nordic countries is not always very bright among data center operators. Many of the interviewees state that some of the international players still see Nordic as a periphery which locates far from the rest of Europe. This *bad image* is hindering the business possibilities of Nordic countries when investors have this type of bias.

"One theme which we can improve if not technically or physically but at least by thinking of marketing [is, that] we have to get rid of outdated image that Finland and Nordic countries are far from the rest of Europe."
-Key Account Manager, Regional Development Company, FI

"If you have 20 ms to Europe, for the normal data center service user it means nothing. It is maybe only the image that Nordic countries are far."
-CEO, Colocation Data center operator, FI

Disadvantages having small influence:

- A different way to construct (compared to Central Europe)
- Strict regulations
- Slow planning process

Data centers can be massive facilities. Those large scale investments are relatively rare in the Nordic countries. This is one reason why Nordic construction companies have only very little if any references of large data center facilities. Due to lack of earlier references, international data center operators can be skeptical toward choosing the construction companies from Nordic countries for their facility. Especially Finnish interviewees had found that the way of constructing such facilities differs in Finland from what international operators have been used to in other countries. Those Interviewees found that this conflict has caused data center operators big problems for finding domestic main contractors and subcontractors to the data center projects. [42]

"Our way of constructing is different than what operators are used to.--We are used to have fixed price projects here. --It is extremely hard to find companies from Finland to take part of these projects. That is why many of the companies have to be taken elsewhere. Finnish companies are not willing to take part of the construction project management type of projects. "
-Enterprise Site Manager, FI

Some of the interviewees had experienced that the regulations for constructing the data centers are stricter in the Nordic countries than many other countries. Especially international operators have been giving negative feedback about the *long planning processes* and *strict regulations* in the constructing.

"I am wondering if we could improve our planning somehow. It is such a long process and I am wondering if it really has to be so long. I think that the legislator should also consider how to shorten that process."
-CEO II, Regional Development Company, FI

[42] This problem was not discussed with interviewees from Sweden and Iceland.

Different advantages and disadvantages of Nordic countries have been summarized for the Table 6. Bolded characteristics are so called "game changers". These characteristics have for some operators' greater role than one might understand based on the table. *Being close to Russia* or *availability of district heating* for example can be extremely important for some data center operators even interviewees did not find them as the biggest advantages of Nordic countries.

Table 6: The different advantages and disadvantages of Nordic countries.

	ADVANTAGES	DISADVANTAGES
BIG THINGS	• Free cooling • Political stability/Safety of the country • Cheap energy (electricity) • **Being overall economical for data center operators**	• Small domestic markets/Clients are far
MODERATE	• **District heating solutions** • **Green energy** • Stable electricity grid • Highly skilled workforce • Fiber optic networks	• **Latency** • Expensive operating (High telecommunication costs) • Bad image
SMALL INFLUENCE	• **Close to Russia** • Security of data • Stable bedrock and stable nature conditions • Clean air	• Different way to build/No relevant experience • Regulations (longer construction time) • Slow planning

4.4.3 Comparison between Nordic countries from the perspective of data center operators

Most of the interviewees found that international operators often see Nordic countries as one market. This was considered quite logical since countries share many similar characteristics. However, there are also some differences which can be significant for the international investors when planning a data center investment.

As mentioned already in the earlier chapter (Chapter 4.4.1), many Finnish interviewees had a vision that Sweden has been the most active player among Nordic countries in the big arenas. Many of the interviewees both Sweden and Finland had common opinion that especially good data center promoting has been in Northern Sweden. In the Northern Sweden four municipalities have created a coalition called The Node Pole which promotes regions potential for data center operators. Their most well-known reference is Facebook which has its data center in Luleå.

> *"Sweden is ahead of us [refers to Finland] in the marketing. They have understood the importance of co-operation quite well. Swedes are doing very good job in marketing."*
> *-Key Account Manager, Regional Development Company, FI*

The advantages of Norway and Iceland can be found in the energy sector and especially in the energy production. Iceland produces practically 100 percent of its electricity by renewable sources when Norway fulfills about 97 percent of its electricity need with renewable sources (Orkustofnun 2014 p. 4; Norwegian Ministry of Petroleum and Energy 2015 p. 24). Norway and Iceland both have a lot of hydro energy which many interviewees considered together with wind energy very desired for the international data center operators.

> *"For Norway, a very strong argument is the massive amount of hydropower. They have a branding advantage in that sector compared to Finland"*
> *-Key Account Manager, Regional Development Company, FI*

> *"Iceland is very competitive when it comes to power. Iceland offers only green power solutions and the power grid is 100 percent green. --Iceland has only used part of its resources so there is a lot of power to harness in the future in Iceland."*
> *-Project manager, Invest in, IS*

Sweden is also positioned relatively well in the energy issues and has great hydro power reserves. However, Sweden produces a lot of its energy also by nuclear power. Denmark and Finland have a big share of their energy production based on renewable sources. Still, compared to three other Nordic countries they are using much more fossil fuels in their energy production (see Figure 23). Denmark and Finland are also more reliable on the imported energy. Denmark's advantage compared to Finland is big wind energy production.

> *"In Finland, we have a lot of to do with energy production. If we think about the brand, it is not very ideal that international actors know that here is not that much energy self-sufficiency. It is a handicap of Finland compared to other Nordic countries. -- We are importing electricity from Russia, which might not be the best reference for Americans."*
> *-Senior Consultant, FI*

However, when a data center operator comes to Nordic countries, it does not necessarily have to buy its electricity from the same country where it operates the facility. For example Google is buying their renewable energy from Sweden even the data center is placed in Finland. Still, some of the interviewees considered this as a minus for Finland.

> *"Sweden is better positioned in the electricity issues [than Finland]. The fact that Google is using Swedish wind power is a small indicator of that. Finland is behind in the energy issues."*
> *-City Manager, Small city, FI*

Also, opposite opinions were expressed about the importance of renewable energy in the decision making.

> *"[Discussing about the green energy in Nordic countries]. It is not a reason why someone would not come to Finland. Being honest, the cheaper electricity you have [the better]."*
> *-CEO I, Regional Development Company, FI*

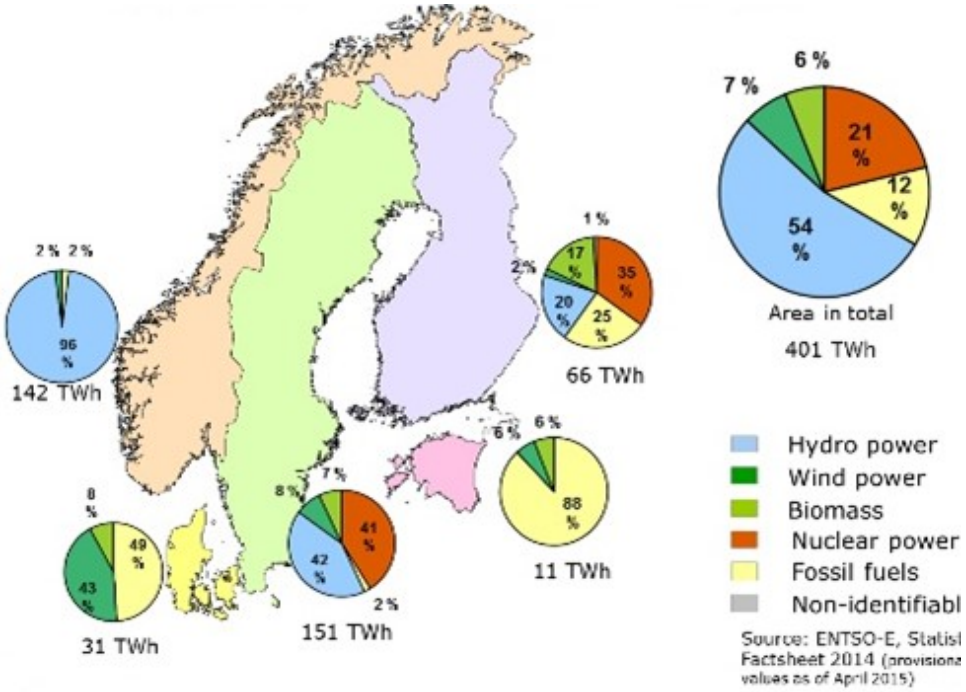

Figure 23: Electricity generation mix in the Nordic market in 2014 (Finnish Energy 2016).

Common for all the Nordic countries are security and political stability which were also underlined by many interviewees. Natural conditions are also relatively similar within Nordic countries except Iceland. Iceland's nature is very unique even in the world's perspective and they have both volcanoes and earthquakes which can be seen as big risk sources for operating a data center. However, the interviewee from Iceland did not see big risks in Iceland and considered Iceland even the most secure location for data centers among Nordic countries. [43]

> *"We are selling Iceland with the safety argument. Iceland is safe. -- My personal opinion is that the security in Iceland is better than in other Nordic countries. --It is much easier to access to [other] Nordic countries than Iceland."*
> *-Project manager, Invest in, IS*

[43] Data centre risk index (2013) ranks Iceland to the 7th place in their annual ranking and second out of Nordic countries (Sweden placed 3th) (see Chapter 2.6.5). Still, in the category of natural risks Iceland is placed to the 18th place out of 30 countries which is significantly lower than Finland's (1st) or Sweden's (3rd) position.

The climate is not making big differences between Nordic countries. Data center operators in all the countries have possibility to use free cooling all year round and chilly climate can be considered as an advantage to all the countries. Islandic interviewee described Iceland's weather being suitable for data centers by the following way:

> *"Actually, the climate [in Iceland] is very good for data centers because it is stable all year round. [There are] no extremes. On average in January is about 0.5 °C and in July 14.5 °C. In Luleå, you probably have minus 25 °C. It is more dramatic [climate there]."*
> *-Project manager, Invest in, IS*

Nordic countries are known for their highly skilled workers and good education. Especially Finland has been internationally well known for the good educations. Sweden and Finland have also a strong background in the IT sector and talented workforce which many interviewees underlined to be important for the international data center operators at least by thinking of the brand of the countries.

> *"Finland and Sweden are strong engineering countries. Both have high skilled [workers] in electronics, computer science etc. We had Ericsson and you [Finland] had Nokia."*
> *-Investment Consultant, SE*

Norway was not considered having as strong reputation as high-tech country which might affect on international operators interest toward the country.

> *"The disadvantage of Norway is that they are not profiled as hi-tech country."*
> *-Senior Consultant, FI*

Norway also has slightly different approach toward data center business than other Nordic countries. They are not just selling the free sites for the data center operators but also constructing all the relevant infrastructure (building and other facilities) by themselves.

> *"Norway has a bit different model than others. They build all the infrastructure by themselves and then search users for their facilities."*
> *-Head of Industry, Invest In, FI*

A different geographical location of different Nordic countries is also causing some differences to their data center market potential. Finland has a special status for serving Russian data center operators. Location next to Russia gives possibility to offer data center services for Russian clients with lower latency than other Nordic countries. Norway has similar advantage for the clients in the UK, and Denmark to the data center operators in the Central Europe. Iceland has the best potential to serve clients in the Northern America.

> *"Finland has special status between Europe and Russia."*
> *-Key Account Manager, Regional Development Company, FI*

> *"In Norway, they have focused on serving UK's market."*
> *-Business Advisor, Regional Development Company, FI*

The new submarine fiber optic cable (C-Lion) was also discussed in the interviews. New cable connects Finland and Germany by a submarine fiber optic cable. Interviewees considered the cable as a positive investment for the whole Nordic.

"The Baltic Sea cable provides Nordic countries an additional fiber route to the continent."
-Chief Commercial Officer, Regional Development Company, SE

Most of the Finnish interviewees considered the new fiber optic cable being a big asset for Finland in the future when interviewees from other Nordic countries found it more like a normal infrastructure investment having only relatively small effect on the competition between Nordic countries. Many interviewees underlined that fiber optic network improvements are happening constantly also elsewhere and one single investment rarely changes the competition significantly. However, some of the interviewees speculated that much bigger impact on the total potential of Nordic countries could be achieved by the Northeastern Passage Undersea Cable (also known as Arctic Connect). Still, the realization of that cable investment was not seen very potential within the next few years.

"The new cable of Cinia is going to improve our [Finland] potential significantly. It improves our competitiveness but if we get the Northern Sea Route cable then it will bring also Asian operators here. Everyone will get more interested in us then."
- Sales Director, Regional Development Company, FI

Heat recovery solutions are more likely to rise their importance in the future also in data centers. Most of the Nordic countries have district heating systems in the cities (was discussed already in the previous Chapter 4.4.2) which gives the possibility to use data centers excess heat in the heating of cities.[44] Many of the interviewees found that heat recovery can benefit those Nordic countries which have harnessed district heating the most. Still, there are many other possibilities to use the excess heat than district heating solutions which makes the speculations of the heat use hard to predict.

"I see that the heat recovery will be important especially when we speak about the massive data centers of multiple MWs."
-Managing Director, Consultancy Company, FI .

The summary of the comparison between Nordic countries (Table 7) shows different advantages and disadvantages of each Nordic country according to interviews (each of the advantage or disadvantage was mentioned at least by one of the interviewees). From the table should be noted that different advantages/disadvantages are compared to other Nordic countries not to other competitor countries. Since most of the interviewees came from Finland and Sweden those countries received the most attention in the interviews which explains their dominance in the summary.

[44] In Iceland district heating is commonly utilized. However, Icelandic interviewee reminded that they have plenty of geothermal heat so using data centers for heat production does not necessarily make sense.

Table 7: Summary of the advantages and disadvantages of different Nordic countries compared with each other according to interviewees. *An Icelandic interviewee considered Iceland the safest of all Nordic countries.

	COUNTRY	Finland	Sweden	Norway	Denmark	Iceland
ADVANTAGES	***Location:***	Close to Russia		Close to UK	Close to Central Europe	Close to UK and the U.S.
	Energy:		Green Energy	Green energy (Hydro power)	Wind power production	Green energy
	Waste heat:	District heating	District heating		District heating	
	Earlier references:	Google, Yandex	Facebook			
	Education:	Highly skilled workers (IT-business)	Highly skilled workers (IT-business)			
	Co-operation:		Strong co-operations between municipalities			
	Energy Taxation:	Lowered energy tax for data centers				
DISADVANTAGES	***Energy:***	Vulnerable energy production			Vulnerable energy production	
	Resources:	Limited resources to promote data centers				
	Image:		Data control (monitors cable bound signals passing borders)	No high-tech image Hard accessibility of dc-sites		* (Risks from environment)
	Market size:					Very small domestic markets
DEVELOPMENT TARGET	***Energy:***	More renewable energy production Less dependency of imported energy				

4.5 Theme 3: Data center trends

Predicting the future is always a hard task. In the interviews, the future scenarios were asked for the interviewees and how they see the future of the data center business. However, one should note that in the data centers industry changes in the technology are rapid, which causes uncertainty for assessing future trends. One of the interviewees described the rapid development in the data center industry by giving a practical example of how fast development can be:

"The technology in the data centers is developing fast. If you open two same kind of data center facilities, one today and another after one year, the technology inside the facility plus construction solutions are more likely to be already different."
-Senior Consultant, FI

Different data center trends are classified into three different categories to ease to understand how big role particular trends are estimated to play in the future. Classification is based on the combination of the number of interviewees discussed about the trend and interviewees' vision about the importance of the trends. Some of the smaller trends are also categorized under one, bigger trend. Different trend categories are:

1. Megatrends
2. Major trends
3. Other trends.

One should note that the classification into different trend categories has been done after interviews by the researcher. In the interviews different trends of data center industry were discussed without classifying their extent or importance.

1. Megatrends:
Trends were classified as megatrends if they are not only the trends of the data center industry and have significant affects also to the other industries and other sectors of life. *Green energy* was considered as a megatrend since it is an international trend which is not just related to the data center business but the whole energy production. Other trends mentioned in this same category (megatrends) are trends which are related to green energy megatrend without being actually megatrends.

Countries around the globe are making efforts to mitigate climate change (often called as gigatrend). One of the ways in that battle is sliding away from the use of fossil fuels and starting to utilize green energy sources. Using green energy sources has become important already but its importance is more likely to grow in the future together with the idea of carbon neutral society. A good example of this kind of development was the climate conference in Paris 2015 where countries decided to decrease their emission from the 2020 onwards (see Ministry of the Environment 2015b).

In the interviews, the general opinion was that the importance of green energy grows also among the data center operators. However, many of the interviewees found that green energy is already very important for at least the big international data center operators and they are investing large sums of money for being able to use green energy and to look "green".

"There will be an increasing requirement to offer green energy. But it will certainly be a prerequisite and not a "unique selling point."
-Chief Commercial Officer, Regional Development Company, SE

Using green energy was considered important also for the image of the data center operators. Some of the interviewees said that the "greenness" of those companies is often highlighted also in their marketing materials.

"Everyone says that it is important for the image, that they [data center operators] use green energy. It can be seen also in the PR-pictures."
-Head of Industry, Invest In, FI

One of the interviewees wanted to see also more variations in the green energy production (e.g. *bio energy*) since now the favored solutions are often either wind or hydro power solutions.

> *"We have here [in Finland] this bio energy sector which we are into talking about. If someone founds ways of combining bio energy sector and data centers, it might be a very interesting concept. It is something that they have not yet been thinking about."*
> *-Managing Director, Consultancy Company, FI .*

Together with the green energy the importance of the so called *ecosystem thinking* is more likely to rise among data center operators. Basically, ecosystem thinking means that data centers are no more seen as individual facilities, but more likely as a part of the urban energy production – first using the electricity in the IT equipment and then turning it into heat to be used in the district heating, laundries, greenhouses or many other applications. Many interviewees found that so far the "greenness" of data centers has been measured with the low PUE values and the percentages of energy produced by renewable energy sources. In the future the "greenness" of data centers will be also measured with the use of your waste/excess heat. Data centers will change from being only energy (electricity) users to energy producers. This means that future data centers are maybe not just data processing facilities and data storages but also important parts of the energy production palette.

So far the excess heat from data centers is often not utilized in any way. In the future data centers might become more integral parts of the urban structure and some of the cities heating demand can be fulfilled with the excess heat from data centers. This is what ecosystem thinking is all about. Common vision among most of the respondent was that data centers will become more integral parts of the urban structure in the future and the use of their excess heat is growing.

> *"We believe that in the future solutions waste heat has to be utilized. We have noticed that there is an active discussion going on about the possibilities of waste heat.--Data centers are seen as part of our energy palette where we want to use green energy. In the data center this green energy is converted into heat [which is] then delivered to the society."*
> *-CEO, Colocation Data center operator, FI*

There are already some existing solutions where excess heat from the data centers is used to produce district heating for the city purposes. With the new heat pump technologies, the temperature of the data centers excess heat can be raised enough high that it can be utilized in the district heating systems making data centers already substitutes for other heating plants. There are also applications where data centers excess heat is used without any heat pumps to heat e.g. the buildings in the surrounding of a data center.

> *"The importance of heat recycling, like in the other industries, has become more important in the negotiations with data center operators. They [they refers to data center operators] want to know if we have some use for their heat. Its [=waste heat] importance has risen. It is no more just the question if we have electricity available but also if we have use for their heat."*
> *- Sales Director, Regional Development Company, FI*

There are already many ideas of utilizing data centers excess heat. Excess heat could be used e.g. in the laundries, greenhouses, fish farms or sewage farms just to mention a few of the

examples discussed in the interviews. One of the interviewees was also pondering the potential of combining data centers with different *energy storage* applications.

> *"One of the things being big game changer in the future is a battery capacity. The whole industry tries to achieve better battery capacity. What happens then [when it is realized]? I don't know."*
> *-Investment Consultant, SE*

In the interviews, the common believe was that the use of excess heat of data centers is more likely to become important in the future. Using excess heat offers significant income potential for data center operators and they can start selling the heat which used to be only a disadvantage in the past. If the trend of ecosystem solutions becomes a big hype, new data centers are more likely to be built close to the urban structure where the need for heat is big and it can be easily utilized.

2. Major trends:
In the interviews, five major trends were found. Trends were classified as major trends if they have significant effect on data center industry, but no effect or only very minimal effect on the other industries.

Interviewees considered that the trend of placing data centers in the chilly locations will remain as one of the trends of data center industry also in the future. By following that idea it is more likely that many new (large) data centers will be placed in the locations having good potential of utilizing *free cooling*.

> *"In the massive scale north is competitive. We see that the cold climate here is still an advantage because of the better cooling efficiency. I think that the advantage has gone smaller since servers can run in the hotter temperatures. -- The advantage has gone smaller but not disappeared. Especially the difference can come from the fact that you might not need here [where the climate is a few degrees lower] any adiabatic[45] cooling at all."*
> *-Managing Director, Consultancy Company, FI .*

Nevertheless, some of the interviewees were somewhat concerned about future technology development and possibilities to run servers in the higher temperatures which could change the climate advantage of Nordic countries.[46]

According to the interviews the need for data centers will remain high or grow in the future. According to that statement, *the increased demand for data centers* was considered as one of the future trends. Some of the interviewees were even predicting very significant growth in the data center market.

> *"There is a common understanding that the amount of data will grow together with the amount of data centers – this is sure."*
> *-Key Account Manager, Regional Development Company, FI*

> *"There is a growing demand [for data centers], more than anyone can probably guess."*
> *-Investment Consultant, SE*

[45] Adiabatic cooling is a variation of air side cooling which uses also the water evaporation to cool the air (McFarlane 2011).
[46] Technology development and servers running in the hotter temperatures were discussed in the Chapter 4.4.2

One of the trends which some of the interviewees raised up was the *growing need for cloud solutions* meaning that in the future growing amount of companies are more likely to utilize different cloud solutions in their data management and processing. Owning a data center is an expensive cost. For many companies outsourcing at least some of the data center related operations is possible development in the future.

> *"When I look at the data center magazines daily I have noticed one big change. The change is that the amount of cloud services has grown significantly. New clouds and new cloud applications pop up every day and "everyone" wants to have own cloud. -- I think that cloud services are going to grow and companies are placing more of their data to clouds. I see that the significant growth in the cloud services is one of the biggest trends now."*
> *-Head of Industry, Invest In, FI*

Security was seen as a trend in the future. Many of the interviewees said that the importance of data security has risen especially after the "case Edward Snowden and NSA". Some of the interviewees were also underlining that if security issues will be emphasized in the future it might guide greater amount of new investments to Nordic countries which are often seen as secure places for data.

> *"The importance of security can be emphasized [in the future]."*
> *-Business Advisor, Regional Development Company, FI*

One of the trends of data center industry which can be seen already is the *increased requirements for data centers*. This means that operators are very well informed about the circumstances in the different regions and the quality of the sites has to be very high to be able to compete against others. Some of the interviewees thought that the competition for new data center investments will become even fiercer in the future which means that the requirements for data center sites are also more likely to grow.

> *"After a few success stories, the interest toward Nordic countries has increased. This has meant that there are much more sites for operators to choose. To succeed in this competition you have to offer your clients your own value proposition based on your strengths. In addition to this, you have to have high class sites to offer because the requirements have risen to the whole new level"*
> *-Senior Consultant, FI*

3. Other trends:
Trends were classified for being *other trends* if they were estimated to affect only some of the data center operators or being more generic practices of the industry than future trends of the industry. However, some of the *other trends* can be very important for some of the data center operators and guide their future activities.

One of the trends discussed in the interviews was the size of the data centers and if it is going to grow in the future. Many of the interviewees reasoned that the size of the data centers can still grow in the future but there is no certainty that the development will lead to that direction. However, many of the interviewees admitted that by having large scale it is possible to achieve cost savings and other type of economies of scale desired when building these large facilities. On the other hand high security risks of massive units were considered to limit the growth of data centers size together with the technical restrictions (i.e. the capacity of electricity grids can set limits for the size of single data centers).

"The size of data centers is growing. Companies want to consolidate their data centers in Finland and in Europe by doing M&A. Big global operators are growing bigger and bigger. They [data centers] are more likely to grow in size. Still, there will remain a need for geographical distribution since one should not keep data only in one place."
-CEO, Colocation Data center operator, FI

Still, some of the interviewees found the future very interesting since many companies have very different approaches toward their data centers size. Some of the interviewees also pondered if there will become some standard (= optimal) size for data centers.

"I think that data centers cannot grow too big in size. -- Especially if you think about the use of your excess heat, there will come some limit in size. -- I think that we are living some kind of revolution at the moment. -- [Interesting questions are:] What are the limits for the data center size? What is the optimum size? How should you arrange your distribution of facilities? What is your energy efficiency and how you take care of the environmental issues?"
-Enterprise Site Manager, FI

One of the trends mentioned in the interviews was *all the operations lowering the costs*. Lowering the costs in the data center operating can be achieved by many ways but maybe one of the most concrete is making the cooling process more efficient. Technological development will also bring more energy efficient servers and maybe servers producing less heat. However, improving the efficiency and lowering the costs is a constant process in almost all of the industries so calling it as a trend of data center industry is open to interpretations (reason why it was classified for *other trends*).

One of the interviewees found *modular design* as a future trend of data centers.[47] Many of the data centers are already build from certain sized blocks or modules. Similar blocks can be added later to the data center and data center can be built gradually to meet with the current demand.[48]

"I think [one of the new trends] is a modular design. I have seen this trend growing its importance."
-Head of Industry, Invest In, FI

Table 8 shows the summary of different data center industry trends identified in the interviews. One should note that in the first category *Megatrends,* only the *green energy* is considered as a real megatrend. Other trends in that category are data center trends which are linked to the megatrend *green energy* without being megatrend by themselves.

[47] Even modular design was not considered as a trend among other interviewees, some of the interviewees were discussing about modular data centers potential in brownfields.
[48] Typically there are two kind of modular data centers: container and modular. In the container data center the data center technology is fitted into ISO container. Modular data center means facility which is built from prefabricated components. Container data center is not the same as modular but modular data center can consist of container data centers (modules) (Normandeau 2013.)

Table 8: Trends of data center industry. Numerical value describe how many of the interviewees mentioned trend in the interviews.

Megatrends	**Green energy**	**14**
	Ecosystem thinking	*12*
	Using the excess heat	*6*
	Energy storage	*1*
	Bio energy	*1*
Major trends	Free (air) cooling	12
	Increased demand for data centers	7
	Cloud solutions	4
	Security	4
	Increased requirements	4
Other trends	Bigger/Increased size of facilities	3
	Operations lowering the costs	2
	Modular design (own design)	1

5 Discussion of the key findings of the interviews

In this section (part V) of the thesis the findings of the thesis are discussed and analyzed. The findings of each of three themes are discussed individually similarly as in the previous chapters. The idea is that each of the discussion themes gives answer to one of the research questions by highlighting the key ideas found in the interviews.

In addition to the discussion of each of the themes, the Nordic future in data center industry is analyzed as kind of separate part. At the end of this section is a table which summarizes the key ideas of this thesis and gives some guidelines how finding can be utilized in the future.

5.1 Theme 1: Brownfields in data center use

When thinking about the old industrial sites (brownfields) in the data center use there are a lot of positive aspects to be highlighted but also some negative ones which should not be ignored in the decision making. According to the findings of this thesis, data center operators can benefit for constructing their data center to the brownfield environment.[49] However, this is not always the case and in many cases greenfield environment can offer less risky, secure and most importantly economically better solution.

According to thematic interviews, greenfield sites become often economically cheaper than brownfields since there is no need for conducting expensive modifications and operators can start from the clean table without worrying how to fit their concept to challenging environment. Especially big data center operators are used to duplicate their data center concepts in the different places so coming to the old industrial environment where buildings already stand would mean expensive planning and completely new way of thinking for being able to adapt to alien environment. This was not just the finding of the interviews and already in the literature review one of the problems linked to brownfields was that they are often designed for one special purpose which makes those environments hard to be harnessed for the new use.

[49] Most of the positive aspects of brownfield sites for data centers were identified in the interviews but some were also found in the literature review.

According to interviews, only a limited number of brownfields are suitable for the data center use. The requirements for the data center sites are exactly the same no matter if the site is greenfield or brownfield. One of the interviewees summarized data centers need especially well:

> *"The place for a data center is decided considering the site itself but also where is electricity and where are the communications [fiber optic cables]. If you have those, you can choose the cooling according to your site, if you have water available or so…"*
> *-Enterprise Site Manager, FI*

So we can say that data centers (large single operator data centers) need at least a combination of four things: *enough electricity available, good fiber optic connections, suitable cooling solution* and *right physical aspects of the site*. If those key features can be provided in the brownfield environments, brownfields become competitive with greenfields. Of course it should be noted that there are plenty of "smaller factors" affecting investors' decision which were discussed in the literature review (see e.g. Chapter 2.6.4). My personal vision is that if you are able to offer those four features in the right manner in the site you are selling or promoting, data center operators are surely interested in what you have them to offer.

However, fitting data center into old industrial environment or building can be difficult and only in certain cases justified. Even those four features would be met in the brownfield environment, it is often just not enough. Existing buildings are usually difficult to harness for the data center use: The more corners and pillars are in the buildings the harder is to fit them into data center use. Difficulties with the brownfield sites did not come as a surprise but I as a researcher assumed that brownfields will be in most of the cases cheaper solutions (than greenfields) and also relatively easy to be adapted for the data center use at least when we are speaking about the brownfields in this research context. Most of the interviewees, however, considered brownfield sites difficult and often more expensive options[50] than greenfields. Therefore many of the old industrial sites (brownfields) have to be assessed very carefully to identity if they have real potential in data center use or if some other use would be more realistic.

Interviews revealed that there should be something unique in the brownfield environment to make investors interested. This unique element can be for example *central location, heat recovery possibilities* or *some benefits of the existing infrastructure*[51] just to mention a few ideas found in the interviews. At least that unique element has to be something which makes brownfield site unique among the other sites (read: greenfields) and rises investors interest. However, according to findings of the interviews the unique element for data centers is very rarely the building itself.[52] This was a small scale surprise for me since the definition for brownfields was deliberately defined the way that existing buildings were assumed to have a great value also for the new users (= data center operators). However, in that regard data centers differ significantly on many other businesses where the building itself has a great value.

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[50] Expensive in terms of the combination of sales price and construction costs.
[51] Supportive infrastructure was seen as an advantage of brownfields also in the literature review (Chapter 2.4.2).
[52] The building itself is often so small portion of the total cost of data centers that operators are not seeing it as unique thing and often it is seen more as disadvantage than advantage.

The most important in the brownfield environment is to bring the investor added value compared to greenfield sites. According to interviews, this added value can be achieved e.g. by lowering the investment costs. Investment costs can be lowered for example by utilizing the existing infrastructure and using the already existing *fiber optic networks* and *electricity grid.* The added value in the brownfield environment can also be achieved *by the decreased construction time* which might be possible to achieve by using the existing planning or utilizing old structures for new business purposes. However, according to findings of the interviews the added value does not have to be related only to the physical environment and can be based on more abstract things like the public image of the company. In the literature review and interviews was noticed there are already examples of approaches that kind but they are still in the minority.

In the interviews many ways for boosting data center investments in the brownfield environment were found. The most important according to interviewees was to *know the environment*. This should be understood the way that the sales organization knows the strengths of the environment and offers the site for the right customers. The key idea is to understand especially why an investor would choose just that particular site instead of other sites. Important questions for the site owners are for example: Why should investor choose brownfield site instead of greenfiels and what is the added value that particular brownfield site can offer for the investor. It was noticed that especially Finnish interviewees were finding a lot of place for improvements in that part of the brownfield promotion.

One of the interesting ideas identified in the interviews was to take advantage of the older references and utilize other data center operators in promoting. Based on the findings of this thesis and my personal opinion, those operators should be used actively in promoting the brownfields if possible. It is sure that many investors get more convinced by the brownfield possibilities when they hear experiences of other companies already running similar or the same business in that type of environment. In Finland for example there are already examples of efficient use of brownfield environments in data center use both in large data centers and smaller colocation data centers. Those examples should be presented also for the potential investors when promoting new investments possibilities (= data center sites). Those practical examples are delivering very valuable information to the investors and helping them to identify both the strengths of brownfield sites and the possible difficulties.

One way to increase the interest toward brownfields is to rethink the users of the sites again and offer sites not only to mega or large data center operators but also to medium sized operators. According to interviews, small data center operators usually construct their data centers on their home markets so they are not very potential of making foreign investments to the old industrial environments in Nordic countries. However, there are many international medium sized data center operators running data centers in the size of a few megawatts (e.g. 5-10 MW). Those operators could be potential investors also for the old industrial sites (brownfields).[53]There are also some examples of medium sized data center operators running successfully their data centers in the Nordic countries – shows that operating data centers of that size can be economically profitable in the brownfield environment.

[53] Reasons why medium sized operators should be considered as potential clients:
1. The amount of those operators is way greater than the amount of mega data center operators (Internet service producers).
2. Their needs for the infrastructure are expected to be bit lower than with the mega data center operators.

New types of businesses need data centers in the future. Actors in the businesses like mobile gaming and Bitcoin mining for example are more likely to need data center capacity in the future together with many other Internet related services. There are also plenty of new social media applications released every day and some of those can grow into success stories like Facebook, Twitter or YouTube which are already the biggest users of data centers. For the companies having great growth potential brownfields can offer an ideal platform to start running a data center since the space can be filled step by step (e.g. by using modular solutions) and company is not forced to invest in the new construction at once. Those type of companies should be seen as potential future client also among investment organizations and site owners. There is always a possibility that after time those small operators are able to grow and buy/rent the whole brownfield property even they would start from small by renting only part of the property. At least keeping an eye on those mentioned businesses is recommended for all the actors in the data center industry.

Turning interest toward smaller operators does not mean that large scale data center operators should be ignored. Smaller operators (= medium-sized data center operators) should, however, be taken into account together with the large scale operators in the marketing. This kind of marketing strategy was considered in the interviews as a right way of doing the marketing. Widening the clientele from big operators to somewhat smaller operators also offers more possibilities to get clients to both greenfield and brownfield sites. According to the findings of the empirical part of this study and my personal vision, sales organizations should be at least open for the smaller operators and be active for answering the questions of those operators in the future and not only concentrate on mega size operators. One of the proposals of this study is to consider chopping brownfield sites into smaller parts to make circumstances more suitable for smaller data center operators. This kind of approach should be considered at least in the big old industrial sites such as paper mills etc., especially in case property has risen strong interest among medium-sized data center operators.

The idea of expanding the interest toward medium size data center operators is quite rational since the amount of operators needing very large data centers facilities (size of tens of megawatts) is limited. Typically mega data centers have been used in the segment of big Internet service producers such as Google, Apple, Microsoft and few other international Internet era enterprises. In addition some of the international colocation producers are operating very large facilities nowadays. Still, the amount of operators in the segment of "mega data centers" is relatively small and most of the data centers are built in the smaller size.

In the marketing, the positive element of the brownfield sites should be highlighted and especially sites located next to cities should be promoted by underlining the advantages of the central location. Central location was identified as one of the advantages of many brownfield sites especially in the interviews but also in the literature review. Brownfield sites should be also seen more as individual properties which should be taken into account in the marketing. One important finding in the interviews was that at the moment there is often a problem that both greenfields and brownfields are marketed with the same sales arguments in the same "baskets". This kind of approach is not very ideal for the brownfield sites and I personally recommend that brownfield promotion should be done by identifying the strengths of brownfield environments precisely and highlighting those positive elements in the marketing. Important is also to be able to show investors why those site characteristics

would benefit them and what kind of value the existing environment would bring to theirs business.

In the future, when the amount of ecosystem solutions is more likely to grow and the use of data centers excess heat will become greater (see the data center trends in Chapter 4.5), sites that are located far from the city structure are more likely to get less attention (both greenfields and brownfields). According to the findings of the interviews and especially by thinking of the potential future trends of data center industry, data center investments are no longer very potential in places that are located far from the urban structure. For those sites primarily other uses than data centers should be considered. My personal prediction is that in the future large data centers will be built (especially in the Nordic countries) to the places where data centers' excess heat can be utilized either in district heating or by other similar applications. Utilizing the excess heat is giving data center operators significant cost savings[54] so we can expect that many operators are going to utilize excess heat some way in the future. Data centers have also grown very big energy users and their share of the total energy usage is more likely to grow still in the future. By considering that, turning electricity into heat which is later used in the other places makes data centers also environmentally more justified – so it is natural development.

5.2 Theme 2: Data center investments in Nordic countries

First of all should be noted that Nordic countries have excellent possibilities to get data center investments in the future. This fact was identified both the literature review and thematic interviews. This does, however not change the fact that only by passively waiting investors to come, desired development will not occur. Nordic countries have to especially improve their marketing and put efforts on the *Invest in* or similar organizations. Those organizations are often the ones which international operators take the first contact with, making *Invest in organizations* kind of gatekeepers of the Nordic data center market.

Important for the region (Nordic countries) is to constantly improve fiber optic networks. The new Baltic Sea cable (C-Lion) between Finland and Germany is one of those projects improving regions position in the competition. However, similar investments should be done constantly also elsewhere (maybe not as massive but similar investments in the smaller scale) and especially Northeastern Passage Undersea Cable should be considered as a near future investment. Northeastern Passage Undersea Cable would make the Nordic region a very interesting place especially for the cloud service producers and Asian data center operators might raise their interest toward the region. Especially Finnish interviewees highlighted the big growth potential of the region that could be achieved by implementing the Northeast Passage undersea cable. The bandwidth of Finland was noticed to have place for improvements also in the literature review so efforts for improving Finland and other Nordic countries position in the international competition are welcome (see Chapter 2.7.2)

Ideas of the fiber optic network improvement are however not new and already Savolainen (2013 p. 78) was discussing the importance of fiber optic network improvements. Northeastern Passage Undersea Cable has got attention also in the media and Finnish newspapers have discussed its possibilities regularly (see e.g. Huhtanen 2013; Kauppalehti 2015). Hyyppä and Kramer (2015) estimate that the benefits of the cable would be only to Finland about 1.38 billion Euro plus more than 1000 new workplaces during the next decade of construction due to new businesses. In addition to those international fiber optic network

[54] Cost savings are achieved by selling the excess heat from the IT equipment.

projects, Nordic countries should also improve their domestic fiber optic networks and fiber optic connections between each other.

Together with fiber optic network, Nordic countries should take good care of their reliable electricity grid which is already known as an important sales argument. Also, by improving the portion of green energy in the electricity production the interest toward the region can be kept high. Especially interviews showed that Finland should make efforts to increase the share of renewable energy sources in the energy production and become less reliable on exported energy.[55] This problem was already identified in the literature review as well as discussed with many of the interviewees (see Chapters 2.7.2 and 4.4.3). Other Nordic countries have stronger green energy production and they should concentrate on keeping international investors aware of their excellent green energy possibilities. Green energy is one of the key arguments for getting data centers in Nordic countries so it is important to keep international investors aware of that excellent green energy availability in Nordic countries.

One of the negative issues which popped up in the interviews was a long planning process. Nordic countries should consider possibilities to make the planning process more effective and less time consuming. Especially many Finnish interviewees considered a long planning process as an existing problem. In the worst case, long planning process can even drive data center investors away if the schedule for the investment is very tight. However, many municipalities (in Finland and Sweden) have solved the problem already by carrying out planning prior even starting to promote data center sites. This seems to be a suitable way to handle this "problem" at the moment. Still, interviewees reported also about some recent examples of investments that had taken place in places where conditions were not originally designed for data centers and the planning process was in progress at the time when investor approached site owner. Despite some opposite examples, my personal opinion is that planning should be done before even starting to promote the site for investors. However, the existing planning seems not to be "a must" for getting new data center investment, but it is surely an advantage especially since operators are often in a hurry with the investment – existing planning always speeds up the process.

In the interviews, the importance of different marketing channels was highlighted by many interviewees. In addition to have the data center sites in the lists of *Invest in* organizations there should be other channels for presenting potential sites for data center operators (investors). Data center sites should be easy to find by the investors and they should be presented e.g. in the website of the municipality, private site owner or other organization taking care of the sale. In addition to present your resources in the Internet, it is often an advantage if there is also some marketing material of the site, illustrating how the data center could look in place. Producing that kind of marketing material should be at least considered since it helps to begin the conversation with the possible investors.

To get data center investments the role of sales organizations is very central. Sales organizations should be capable for answering "all the questions*"* data center operators can ask. Themes of the questions which data center operators are more likely to be interested are related to *energy (price and availability), fiber optic connections*, *cooling* and *physical characteristics of the sites.*[56] Those four themes are important for all the data center operators

[55] Denmark is also reliable on imported energy. Denmark's advantage compared to Finland is large amount of wind power.

[56] These are the same issues which were discussed to be important for brownfield sites (see previous Chapter).

no matter how big or small they are or what is their business model. However, there are also plenty of other issues operators might be interested in and each of the operator might have slightly different needs (site selection was described in detail in Chapter 2.6.4). Interviewees had experience that especially international data center operators are very interested also about the region itself and can ask various questions starting e.g. from such themes like the education levels or crime rates in the region.

Sales teams or organization should be able to answer those kinds of questions at short notice. In case there are no sales organization such as regional developing company, municipality or similar, *Invest in organization* of the country can actively support the site owner and help to get required information for the investor(s). Sales organizations of Nordic countries have improved their knowledge in the past few years and most of the organizations promoting data center sites have already relatively good knowledge. However, in the interviews was noticed that the knowledge between interviewees was varying relatively lot which was a bit surprising since all the interviewees were pre-selected for being professionals of the data center industry. Especially big differences were noted between interviewees from different regional developing companies. However, those differences can be explained perhaps by the facts that foreign data center investments to Nordic countries are quite new phenomenon. By considering that fact, it is obvious that some of the regions have noted data center industry potential in the earlier phase and have been able to get already relative good knowledge when some other regions have just started to become interested in data centers business possibilities.

In addition to the important role of marketing and sales organizations, the product itself has to be good. This means that the general circumstances in Nordic countries have to be good and the quality of free data center sites high. To achieve that, each Nordic country should have their own data center strategy which aims to achieve those goals. In Finland for example, *Invest in Finland* has launched Data Center 3.0 growth program which aims to improve general circumstances of data center cluster in Finland by improving marketing, constructing a national data center investment portfolio and making effort for boosting country's reputation among investors. The program has several partners such as Finnish municipalities and regional development companies, all of them being interested in data center industry possibilities (more about the program, see Mattila 2015 p. 21-22). Those kind of programs are examples of how the general knowledge can be increased in the national level by improving the co-operation. My personal proposition is that similar programs should be considered also among other Nordic countries to increase the position of the whole region.

One of the ways, how data center investments could be lured to Nordic countries are different incentives (their role was described in the Chapter 2.6.4). In the literature review the role of incentives was described being especially important for the U.S investors. Different incentives were not taken into account in the findings of the interviews although they were discussed with some of the respondents in the interviews. There were several reasons for the decision to ignore their role in the findings of this study:

1. Incentives were seen only as contemporary ways to attract investments.
2. Data center business was seen often too hectic for incentives.
3. The role of incentives was seen very speculative.
4. Especially the attitude of Finnish interviewees toward incentives was pronounced negative.

However, despite incentives were not taken into account in the findings of the interviews, their role in the brownfield development should be considered at least in the brownfield environments where the contamination is significant.

5.3 Theme 3: Trends

The international massive trend (often considered as s gigatrend) is the climate change and actions to mitigate its effects. One way to battle against the climate change is to shift from using fossil fuels into renewable energy sources. Nordic countries hold an excellent position in this international energy shift since they already have a big share of their energy produced by renewable sources and green energy.

Green energy should also be highlighted in the promotion of the Nordic region for foreign data center investors. Already many of the data center operators are trying to make their business green or carbon neutral by using renewable energy sources. This development had been noticed also among the interviewees of this thesis. Interviewees had a vision that the use of green energy will be the biggest trend of the data center industry in the near future. Nordic countries should be able to react to that trend and be able to offer green energy solutions. Turn toward the green energy production has already been made around the globe and EU for example has a target of having 27 percent of the energy produced by renewable sources by the year 2030 (Työ- ja Elinkeinoministeriö 2015c; European Commission 2016b). Decisions in the Paris climate conference are more likely to speed up the development toward renewable energy sources around the world due to concrete target for mitigating the global warming (See United Nations 2015).

Together with the green energy, different ecosystem solutions are potential future trends. District heating solutions are common in the Nordic countries and data centers should be integrated into those systems. Data centers can become in the future important district heat producers and some of the traditional thermal power plant can be replaced in the heat production. Nordic countries should follow this trend very carefully for being ready to offer different heat utilizing solutions among the first ones in the future. There are also plenty of other applications in addition to district heating where the excess heat of data centers can be utilized. Nordic countries should study those possibilities for being ready to offer those solutions for data center operators in the future. The motivation for data center operators to favor the use of waste heat comes from the new earning possibility (= selling heat). This trend has not yet been widely identified in the data center literature but in the interviews many of the interviewees believed it to be one of the next “big things” in the data center industry.

There was anonymous opinion among the interviewees that the data center market will grow in the future which is more likely to mean that more investments will be targeted also to Nordic countries. To turn this growing demand for data centers into investments to Nordic countries, Nordic countries have to offer high quality sites for foreign investors. Since the quality of the sites has to be very high it might be justified to concentrate on the smaller number of data center sites with excellent circumstances.

The findings of this thesis are proposing that Nordic countries have to find new sales arguments to complement some of the old generic ones such as *cold climate* or *stable political climate*, which might not be enough no longer for bring new investments to the region. New sales arguments can be found for example among the new trends of the data center market. In Table 9 is summarized some guidelines for different data center actors for being able to adapt to the future development of the industry.

Table 9: The key findings of the interviews shown as guidelines for different data center industry actors.

THEME I: OLD INDUSTRIAL SITES (brownfields)		
	ACTOR	**GUIDELINE**
Brownfield	Owners (cities, private owners)	• Know the environment • Consider other uses in addition to data centers
Boosting data center investments	Sales organizations	• Consider the potential of smaller operators • Make the image stronger by offering something unique • Make added value for investor (present calculations, show other references) • Take advantage of the existing infrastructure
THEME II: DC INVESTMENTS IN NORDIC COUNTRIES		
ACTOR	**GUIDELINE**	**ACTION**
Invest in Organizations	"Know the role of being one of the key elements in the country's success"	• Cooperate actively with (cities, land owners) • Present older references to promote country in the industry events (take people from those companies with you) • Keep the quality of the promoted sites high in the country lists
Governments	Take care of the improvements in fiber and electricity networks Take care of the cheap electricity prices	• Take care of the new fiber optic connections to Europe, Russia and (Asia) • Keep low energy taxation (government) and electricity transfer fees
Governments/ Municipalities	Find ways to speed up the planning process	• Find ways to shorten planning time (i.e. find possibilities for exceptions)
Site owners, sales/marketing organizations	Improve the quality of sites	• "Better quality but smaller amount". • Improve the circumstances (clean, harvest, visualize)
	Co-operate with others (other site owners, Invest in, DC cluster)	• Share the information and learn more.
	Concentrate on our strengths and make others aware of them	• Improve especially green energy and ecosystem solutions (find use for excess heat)
	Improve your knowledge	• Take part of the domestic industry events and meetings
	Take part of the international events	• Get new contacts, show yourself
THEME III: TRENDS		
TREND	**ACTOR**	**ACTION**
Green energy	Government	• Improve availability and amount with the use of "carrot and stick"
	Site owners (municipalities, private owners)	• Be creative with the energy sources, keep investors aware of the positive development • Integrate district heating solutions
Ecosystem solutions	Site owners, data center companies	• Find synergies between different actors, be innovative and open toward different solutions
Big growth of industry	All the Nordic countries	• Work hard to get your share of the growth
Increased requirements	All the Nordic countries	• Improve the quality of your sites, answer client's needs, follow the industry, co-operate

5.4 Discussion about the Nordic future in the data center business

The global data center market will grow in the future together with the amount of data. It is realistic to think that part of that growth will be realized in Nordic countries meaning that some of the new data center investments will be made in the Nordic countries. Visible proofs of the potential of the Nordic region are all the previous data center investments and the fact that big Internet service producers such as Google, Facebook and Yandex have already opened their data centers in Nordic countries (two of those projects are introduced in this thesis, see Chapters 2.81 and 2.8.2). More topical proofs of the Nordic potential were witnessed just before the start of this thesis research process and during the research process when two new large scale foreign data center investments were announced in the Nordic countries: Apple decided to come to Denmark (see Chapter 2.7.3) and Hetzner Online announced its intention to open data center in Tuusula, Finland (see more about this investment: Yle Uutiset 2015b). These two new investments are showing that positive vision of Nordic as a data center hub is maybe not that far and at least Nordic is very competitive among other regions. The idea of Nordic economies getting data center industry a new gold mine is, however, still far in the future.

However, none of the data center investment into Nordic countries will become without hard work. Interviewees described the realism of the work behind the investments by the following way:

> *"In the end it is packing your backpack and doing business. Clients are not coming from the digital sources (e.g. websites). -- You have to meet people."*
> *-CEO I, Regional Development Company, FI*

> *"It is just hard work. --In the end it's people doing business with other people."*
> *-Chief Commercial Officer, Regional Development Company, SE*

Without putting efforts on the salesmanship and marketing, investors will not recognize the full potential of the Nordic countries. It is obvious that promotion has to be done with various channels and Internet is a good way to share and present information. Still, people are making the business, so it is essential to meet people and tell about yourself and your business possibilities. Being in the data center industry events is one of the good ways to present yourself and get new contacts.

Just by putting efforts on marketing and salesmanship is not enough. At least as important as marketing and salesmanship are, is the product itself. Having a good product is essential to make investors interested. Countries should make the favorable circumstances for international investors to come to the countries and run business. In that sense data center industry makes no difference to other industries and it should be treated in the same way. Sales organizations and site owners (cities, private owners) should also make their share by taking care that sales organizations have quality sites to offer for the clients (was discussed already in the previous chapters).

According to many interviewees, winning formulas have often been combinations of an excellent product and active salesmanship. One of the interviewees summed up the idea of being perseverance and constantly improving the circumstances.

"It is about constant improvement. We don't have any silver bullets which we set somewhere and then get investments by doing that. It is all about long term improvements in energy, fiber optic networks, salesmanship and marketing."
-Managing Director, Consultancy Company, FI .

If Nordic countries are able to offer competitive circumstances to data center operators to run their business, they are more likely to point their interest toward countries. To be competitive and get investments, Nordic countries have to have *quality sites to offer*, *skilful people in marketing and helping investors* and in the end maybe *a bit of good luck*. The competition for new investments is hard and not only Nordic countries are interested in foreign data center investment. For being able to compete for new investments there has to be enough knowledge about the client's needs and a vision how the industry will develop in the future. Studies of this kind are hoped to increase the general understanding about the data center industry potential in Nordic countries as well as give ideas of the industry's future development.

One of the things which might raise the interest toward Nordic countries is a co-operation between countries in the promotion. At least there should be national level co-operation between municipalities and knowhow should be shared to increase everyone's knowhow (see also the previous chapter). Co-operation does not mean that all the information should be open for everyone. Competition between municipalities is sure a positive thing and keeps the competition alive. Still, co-operation between actors in the data center cluster in the national level would certainly increase everyone's position in the competition. It is obvious that the more new data center investments will be made in the Nordic countries the more aware investors become of the Nordic possibilities – which may lead to new investments.

"When Nordic grows it will be benefit for everyone."
-Chief Commercial Officer, Regional Development Company, SE

The idea of the above citation should be kept in mind in the future. There are good examples of the co-operation at the national level. The coalition of four northern Swedish municipalities (the Node Pole) is maybe the best example of co-operation between different municipalities which has successfully attracted data center operators. Currently the region has 10 different data center operators that can be considered as a true achievement in the Nordic scale (The Node Pole 2015). This kind of co-operation between municipalities seems to have worked well and brought more interest toward the region. Municipalities in Nordic countries could consider if working together with other municipalities could bring advantages in the future. At least many of the interviewees highlighted the Node Pole as a textbook example of a skilful organization which has managed to make itself well known in the data center industry.

One of the advantages of Nordic countries have been cheap electricity. Countries should take care that the energy prices will remain low compared to rival countries in Europe. This kind of work has been made in the Nordic countries and i.e. Finland and Denmark have lowered the energy taxation for data centers and Norway and Sweden are planning to conduct same kind of actions in future.

Promotion of the region has to be done by highlighting the strengths of the region. Especially the importance of green energy and waste heat solutions are issues which are more likely to become important in the future and have to be underlined in the Nordic marketing. Energy issues are the real strength of the Nordic countries and they should be taken good care in the

future. Green energy is an international trend which importance is likely to grow in the future – this trend will benefit data center industry development in the Nordic countries in the future.

In the future, Nordic countries have to make investments to their fiber optic and electricity networks to maintain the good position in the international competition. In the future the Northeast Passage Undersea Cable should be considered seriously and there should be concrete effort to forward the project. The Northeast Passage Undersea Cable could be a real game changer bringing a lot of new investment to Nordic and making the region a read data center hub. At least many of the interviewees were speculating the huge potential of the project and the potential has been identified also in the analysis of the project (see Hyyppä and Kramer 2015).

The importance of the cold climate might decrease in the future and new strengths have to be found (has already been discussed in the previous chapters). However, data center business is one of a few industries where Nordic is competitive in the matter of costs (due to cheap electricity and low cooling costs). In the manufacturing industries competing in the costs especially with many Asian countries is impossible because of the higher labor costs. In data center business labor costs are usually small and account only a small portion of the total costs of operating data center – even huge data centers are operated with relatively small amount of people. Since labor costs are not big cost factors in data centers, are Nordic countries interesting locations for data centers since the biggest cost factors (electricity and cooling) are competitive. However, only in case those biggest cost factors remain small in comparison with the other countries in the future, Nordic can keep its status as desired location for data centers.

There has to be also some geographical distribution in the companies' data center networks and all data centers cannot be placed in one place. Data centers have to be placed also relatively close to the users (clients) in terms of latency. Nordic countries are physically near big markets in the Central Europe and Russia. By getting rid of the old fashioned image of being far, companies from the Central Europe and Russia can be also lured to open their data centers in Nordic in the future.

6 Conclusion

In this section (part VI) the main results of the study are discussed and assessed. The idea is to conclude what kind of knowledge was achieved by this study and as well discuss what kind of basis study constructed for the further research. This section also discusses the quality of this study and introduces terms validity and reliability. Validity and reliability are also assessed in this study context.

6.1 Discussion of the study and the results

The first object of this study was to clarify the potential of old industrial sites (brownfields) in the data center use. This study showed that there is a need for finding new uses for currently empty old industrial sites (brownfields). In this study, data centers operators were introduced as one of the potential users of those sites in the future.

The study showed that brownfield sites have potential in the data center use and some of the future data center investments can be realized in brownfields. However, this study showed

also that in many cases brownfield environment is not bringing data center operators' enough added value for being competitive with the greenfields. Also, one of the biggest problems with brownfields identified in this research was, that operators are used to duplicate their data center facilities in different places which is in the brownfield environment often impossible. Still, some of the brownfields have the potential to be harnessed for the data center use especially due to the advantages of existing infrastructure and central location. For the rest of the brownfields alternative uses should be considered. However, the main goal of this study was especially to identify the strengths and weaknesses of the old industrial site environments in the data center context and to understand their future potential considering that type of business. In that purpose, this study achieved its main goals by identifying both existing problems and possibilities. This thesis did not introduce any other future use for old industrial sites (brownfields) but such further research should be considered in the future (see Chapter 6.4).

The second objective for the study was to find ways how Nordic countries could get data center investment in the future. This study showed that Nordic countries have great potential to lure data center investments in the future due to favorable general circumstances for the data center business. More investments can be achieved especially by being active in the promoting and improving fiber optic networks and constantly aiming for improving the general circumstances. This study also identified some strengths and weaknesses of the Nordic countries related to data center industry. The four greatest advantages of Nordic countries identified in the empirical part of this study were chilly climate (possibility to use free cooling), stable political situation, cheap electricity and cheap operating costs. Those advantages have been identified also in the previous studies such as Nissilä et al. (2014) but this particular study brings the updated information and in addition new ideas of the potential future advantages and how they should be treated. The advantages of Nordic countries were identified both in the literature review and thematic interviews.

This study also introduced the trends of the data center market. The idea was not just to list different data center industry trends but also try to make some estimates how those trends affect data center industry in the future. This study estimated green energy being the greatest trend in the center industry at the moment. Many other trends of data center industry were also identified in the study. Maybe one of the most interesting trends in the future will be *ecosystem solutions*. Ecosystem solutions are ways to combine data centers with other city functions such as heat production (i.e. use the excess heat of data centers in the district heating or in other applications such as laundries, water treatment plants etc.).

Comparing the key findings of this study with previous studies is hard since the academic research about the research themes is very limited. In fact this study was the first study which assessed old industrial sites (brownfields) potential in data center use in Nordic countries. This means that especially in that context this study gives a lot of new information. However, some of the other findings of the study can be compared with other studies. For example the findings of Nordic countries potential in the data center industry can be compared with some of the previous studies. Nissilä et al. (2014) estimated the potential of data center cluster in Finland being significant a few years ago. This study practically comes to the very similar result, however, by estimating the potential of the Nordic countries not just Finland. Nevertheless, the findings of this study can be seen somewhat more critical than the findings of Nissilä et al (2014): This study underlines that the competition for new investments is very tough and even Nordic countries have some advantages compared to rival countries,

each of the investments needs efforts in the governmental level but also among smaller actors in the industry.

Despite Savolainen (2013 p. 76) focused on his Master's thesis especially on the investment criteria for mega data centers in a small city case study approach, he was discussing also about some similar issues discussed in this study. Savolainen (2013) for example recommended electricity tax reductions for Finland. After his study, the electricity tax has been reduced which was seen positive action also in this thesis findings. Savolainen (2013) recommended also fiber optic cable investments for Finland. Those investments were seen also very important in the findings of this thesis in the whole Nordic context. The findings of this study have, however, some contradictions with the findings of Savolainen. Savolainen (2013 p. 84) was recommending Finland data center focused education and university level courses to improve the knowhow among data center industry. This thesis did not come to the result that those ideas were in any way wrong. Still, in this study none of the interviewees was proposing that kind of ideas and actually the knowhow in ICT industry was considered as one of the advantages of Finland in this research.

The trends of data center industry have been discussed also in the other studies. In example Ascierto et al. (2015) identified in their white paper five different data center technology trends for the year 2016. Among those five trends, there were a lot of similarities to this study. In fact trends like modular solutions[57], cloud solutions, increased size of data centers and change in the data centers energy use[58] were trends that were identified in both studies. However, trends were discussed by using slightly different words and there were also some contradictions about their importance in the future[59]. Also other sources have identified similar future trends. Data center industry magazine *Data Center Knowledge* (DCK) identified in their article two of the same data center industry trends as this study: Renewable energy and increase in the cloud services (Sverdlik 2015).

To assess the study in general can be stated that the main goals set for the study were achieved. The idea of the literature review was to construct the basis for the thematic interviews and to tell the background story behind the born of brownfield sites. In the literature review the general technology of the data centers was introduced to make the reader familiar with the data centers characteristics, their purpose and their importance. In the literature review some ideas about the brownfield possibilities were also identified and brownfields sites were evaluated by considering their use as data centers based on the previous literature. The main purpose of the literature review, above all, was to make a reader familiar with the thesis topic and to construct a strong basis for the thematic interviews. So the idea of the literature review was especially to deepen readers' knowledge and introduce the background of the thesis for the reader for being able to understand why the thesis was conducted. In the literature review reader becomes familiar also with the previous studies related to thesis topic, the interest areas of those studies and what kind of knowledge those studies have been able to deliver.

[57] Named as prefabricated data centers in the study of Ascierto et al. (2015).
[58] Means the growing use of green energy and data centers integration to local energy infrastructure.
[59] In the study of Ascierto et al. 2015, the importance of energy shift was seen not to have yet great effect on data center industry. In this study green energy and ecosystem solutions were considered being great trends in the future.

Literature review can be considered being successful and fulfilling the described aims set for it. During the literature review process the main problem was that some of the interesting articles and consultant studies were not available free of charge. Especially topical studies related to the data center market were often not available free of charge even with the Aalto university access. Also, some of the headings which were originally planned to be in the literature review had to be changed during the research process since the available information was considered being not extensive enough. The mind map of the study (see Appendix 3) was a great help during the whole literature review process and helped to find connections between different headings (themes) and to find important topics which were important especially considering the interviews. Literature review prepared myself also well for the interviews by improving my knowledge about the data center industry. Having enough wide knowledge about the data center industry was essential for being able to conduct the interviews.

The second research method was observation. Observation was used as a supportive research method for both literature review and thematic interviews (see Chapter 1.6). Observation meant in this thesis context that researcher followed actively data center industry during the research process and new information was collected from different media (newspapers, industry magazines, TV and Internet). This material is not much utilized in this thesis but it often led to scientific articles which were then used in the literature review. Some of the topical data center themes identified through observation were also discussed in the interviews. Observation was also important for identifying the new data center investments which were often discussed with the interviewees.

The original plan for conducting the observation was to take part in the different industry events but due to the tight schedule of the thesis process it was not possible. The idea of taking part in the industry events and conferences was to collect some notes and get some new ideas for the literature review and the interviews.[60] Industry events like fairs or conferences could have been also excellent places for meeting some data center industry experts and to make some useful contacts. However, even no industry events were taken part during the research process, some of the interviewees were found by browsing through the speaker lists of the previous years. Taking part in the different events could have been also refreshing and given some new ideas which were not achieved only by conducting the observation by described way (=following the media). Still, despite observation was conducted a different way as planned it can be considered being important part of the interview process and given information which was important for the use of other research methods.

The main research method (thematic interviews) was also suitable for the thesis purposes and a lot of new information was collected. Also, the general arrangements with the thesis were successful and no major problems were faced during the research process. However, some smaller problems were identified during the interviews. The sample of interviewees for example did not include as much variation as was original intention. The interview sample should have consisted similar amount of interviewees from each of the Nordic country for being able to access different countries equally. In addition, some organizations are over-represented in the interviews. However, due to a relative tight research schedule for

[60] With the use of observation was hoped to get information which could have been hard to get with other research methods: For example to see how different organizations promote themselves or if the trends identified in the interviews can be also seen in the industry events.

the interviews, some of the original principles had to be changed and interviews were conducted with the respondents that were reached within the time allocated to interviews.

One possible problem in the interview study comes from the different languages. Interviews in this study were held both in English and Finnish (see Chapter 4.1). Because interviews with Finnish interviewees were held in Finnish, their citations in this thesis are translations. However, there was an intention to keep the amount of translations minimal and use only that amount of translations which was absolutely necessary. This means that transcribing was done always with the interview language and only those sentences which have been written in this thesis are translations.

The findings of this study can be used many ways. At the national level, this study gives ideas about the possible actions how foreign data center investment can be attracted to different countries. The ideas and findings of this study are at least hoped to increase the general knowhow in Nordic countries as well as increase the conversation about the importance of some future actions (e.g. fiber optic improvements). For the municipalities and private site owners (e.g. industrial companies) study gives new ideas of the brownfield environment development. Study gives answers for example to the following kind of questions: *What kind of sites have potential for data centers* and *what are the ways how brownfield sites should be developed and marketed for the investors.*

This study gives site owners also ideas, how they should assess their brownfield environments and what kind of characteristics make those sites desired for data center operators. Study should help municipalities and other site owners to identify the main strengths and weaknesses of their sites considering their use as data centers.

The findings about the future trends should be valuable information for all the actors in the data center industry. At least the ideas of the future trends can ease the future decision making and give new ideas where to target interest in the future.

6.2 Quality control

Quality control in the literature review
Since the technology development is fast in the data center industry it was essential to use only those sources of information (articles, research reports, books etc.) which were up-to-date. No age barriers to the used sources were set but the idea was to use as new information sources as possible and to confirm all used information also in the other sources (this kind of procedure was described in the Chapter 2.2).

The quality of the used references was kept high by concentrating on choosing primarily studies, articles and white papers which had been cited widely in the other academic studies or if the publisher was well known. This kind of selection was easy to conduct in those parts of the literature review where the amount of the available sources was very vital: for example there is plenty of academic literature about the technology of the data centers and data centers energy consumption. Still, some of the themes discussed in the literature review have relatively small amount of academic literature and the amount of references which were enough good for the academic research purposes was limited setting some challenges for the quality control.

Quality control in the observation
Since observation was used only as a supportive method for the literature review and interviews, no strategy for the quality control of observation was considered necessary. Still,

if observation would have been conducted by taking part in the industry events (like was the original plan) the quality control would have been important also while conducting the observation.

Quality control in the interviews
Hirsjärvi and Hurme (2006 p. 184) give some practices to control the quality of the interview study during the research process (total of 6 different methods). Those different practices are presented below. Together with the quality control practice, there is a short description how each practice was applied in this research.

1. Having strong interview structure:
In this research, the interview structure was discussed together with the thesis advisor. In those conversations, the interview structure was changed several times and some of the questions were added or deleted.

2. Improving the quality of interviews by having some training interviews:
Prior to the first actual interview, interview situation was practiced by arranging two training interviews. Training interviews were recorded to make sure that the recording systems were working and the recorded voice was enough loud for transcription. Training interviews were not transcribed.

3. Going through the interviews and analyzing them during the research process:
Interviews were not analyzed during the research process. However, no changes in the interviews were notices during the interview process except the behavior of the researcher which became more relaxed after the first few interviews.

4. Taking care of the technical equipment:
In the interviews, two different voice recorders were used (mobile phone and laptop). After each interview, the quality of the recorded material was checked and copied for the laptops hard disk and USB flash drive. Two voice recorders were used to ensure that each of the interviews was properly recorded. Telephone interviews were conducted by using the loud speaker of the phone and only one recorder (laptop). Skype interviews were recorded with the MP3 Skype Recorder (freeware) and mobile phone's recorder (Voice Recorder Pro+).

The quality of the recorded material was perfectly adequate in all recording except one interview which had to be summarized since both of the recordings were too bad in quality (= too quiet voice). A similar recorder combination can be recommended for other researchers.

5. Keeping an interview diary:
No interview diary was used. However, notes of each interview were collected in addition to recorded material.

6. Transcribing interviews as fast as possible:
Most of the interviews were transcribed right after they were recorded. If that was not possible, transcribing was made during the same day or latest one day after.

Hirsjärvi and Hurme (2006 p. 185) say that the reliability of the interview sample depends on its quality. In case researcher has followed the techniques listed above and conducted

research with the required accuracy, we can assume that the research is relatively reliable. However, if there is a big variation between interviews (e.g. in the arrangements), the quality of the recorded material is poor and the researcher does the transcribing different way between the phases of research, the interview sample cannot become very reliable.

6.3 Validity and reliability

Even though the aim of the research is to avoid mistakes, there are always possibilities for errors. Due to this fact, it is important to estimate the reliability of the conducted research (Hirsjärvi et al. 2009). There are different methods to estimate the reliability of the research.

Metsämuuronen (2006 p. 115) writes that typically the reliability of the research has been described with two different terms: reliability and validity. Both of these terms being the ways of showing the reliability of the research.

Reliability of the research means basically, how well the research is repeatable. This means that if the study would be conducted again by using the same metrics in the other place and time, how similar or different the results would be. In case the metrics are reliable, the results are similar to the original study (in case no systematic error exists) (Metsämuuronen 2006 p. 65-69; Hirsjärvi et al. 2009 p. 231.)

Another method to estimate the research is *validity*. Validity indicates, how well the chosen metrics and research methods are supporting the research purposes. In other words, how well the chosen research methods and metrics are able to give results which researcher aims (Hirsjärvi et. al. 2009 p. 231.)

Hirsjärvi et al. (2009 p. 232) say that estimating the validity in the qualitative research is maybe not as simple as in the quantitative research. Reason for this is partly because terms have their origins in the quantitative research and they have been created to the purposes of that kind of research. Hirsjärvi et al. (2009 p. 232) explain that it is one of the reasons why adapting validity and reliability in the context of qualitative research is maybe not even always reasonable.

However, Hirsjärvi et al. (2009 p. 232) advise that there should still be some methods for estimating the reliability of the research in the qualitative research, even the terms "reliability" and "validity" would not be used. In the qualitative research reliability of the research can be improved during the research for example by having precise descriptions of the research practices and circumstances.

Hirsjärvi et al. (2009 p. 232) say that the more precise researcher tells about the research practices and circumstances the more secure reader can be that researcher does not want to hide anything from the readers and the results are truthful. For example if the interview practices are described with the very precise way, can reader estimate by oneself what could have been the possible errors. Naturally researcher's own vision about the potential error sources is also very important information for the readers since researcher is the best expert of his/hers own study. In fact researcher should present all the relevant information about the research practices and circumstances in the study to ease reader to estimate the reliability of the study. In the interview study relevant is to tell e.g. about the interview conditions, the length of the interviews and if some distractions were faced during the research process etc.

According to Hirsjärvi et al. (2009 p. 232), researcher should follow the same kind of precision in all the phases of the study. It is important that researcher is able to tell why he/she has made some interpretations about the material and why he/she has ended up for certain results. Also, using the right amount justified citations can ease the reader to understand the basis of researcher's interpretations. It is good to note that there is also a possibility to compare the research with the other similar studies to assess its reliability.

Hirsjärvi et al. (2009 p. 232) add that one way of improving the validity of the research is also to use multiple research methods. In case researcher gets the same results by using different research methods the validity of the research can be considered good since the same results were achieved even the methods were different (in case researcher is not repeating the same mistakes with every research method).

6.3.1 Describing the validity in this thesis

The reliability and the validity of the thesis were improved in this thesis by having very precise descriptions for all the research phases and procedures:[61] i.e. the literature review process is described accurately in Chapter 2.2[62] and the quality control of the thesis is introduced in Chapter 6.2. The validity of the literature review can suffer slightly from a strategic choice of using Finland as an only example country from Nordic countries. Since the circumstances in all the Nordic countries are not identical to Finland the validity of the certain parts of the literature review can represent too narrow point of view especially if we take into account that the thesis was conducted in the context of all Nordic countries. However, when assessing the validity of this study the main concentration should be pointed toward the empirical part of the study and the main research method (thematic interviews).

Reliability of the study present the possibility of replicate the study (see previous chapter). The empirical research of this thesis was conducted by using thematic interviews. Typical for the thematic interviews is that they combine both structured questions and free discussion about chosen themes. Especially the possibility for free discussion and some randomly generated additional questions makes that type of interview very difficult to be repeated. Noticeable in this particular study was that often the most interesting ideas popped up during the free debate around the interview themes when the interviewees were not forced to answer directly to the question. Those kinds of new ideas are more likely impossible to achieve just by following the structured interview questions and collecting interviewees answers for those questions. That is the strength but also the weakness of the qualitative research method like thematic interviews.

Even by using the same interviewees, interviews are always different and the course of the interviews different to each other's despite the questions would be the same. This fact makes some requirements of *reliability* almost impossible to fulfill in this thesis type of qualitative research. In fact it is likely that the sample of interviewees would also be different by some parts if the study be conducted later.

[61] The way how this kind of procedure improves the reliability and validity of the study was explained in the previous chapter.
[62] Everyone can find the references used in the study relatively easy by using the same academic databases and search terms.

We can assess this research in terms of internal and external validity which are maybe the most typical forms of validity (Metsämuuronen 2006 p. 55, 64). In the internal validity uncertainty can be caused for several reasons. Such things as time, event (e.g. an interview), research metrics, distortions or loss in participants can be reasons for low internal validity. (Virtuaali Ammattikorkeakoulu)

In this research, relevant for the internal validity are time, the event and lost in participants. Time refers to the time between the events (interviews), meaning that there can happen various things between conducting the first and the last interview. For example in the case of data center industry rapid technology development can cause changes in the circumstances. In this research, interviews were conducted during the period of two months. During that period of time the circumstanced in the industry remained similar and no significant changes were noticed.

Interviews were conducted each time with the same kind of procedure. However, some of the interviews were conducted via phone or Skype instead of face to face conversation. Different ways for conducting the interview situations can have influenced slightly to the results obtained.

In this research, especially important was to find "right people" for the interviews. Still, there were several people and organizations who were originally intended to take part of the interviews but unfortunately were not reached or did not take part of the interviews for other reasons. Loss in participants can be considered as the biggest source of uncertainty in terms of internal validity in this research. Since the interviewees came only from three Nordic countries their vision of the data center industry might have been also a bit restricted and represented only the inner vision[63] about the discussed issues. In the ideal situation participant of the study would have represented at least all the Nordic countries (about the same amount of participant from each of the country). In addition to those people some of the representatives outside of the Nordic countries and people from big multinational data center organizations would have increased the validity of the research.

External validity answers the question: how well the results of the study can be generalized (Metsämuuronen 2006 p. 55; 64). This research was conducted in the Nordic context. Still, participants only from three Nordic countries took part of the interviews most of the participants coming from Finland. This means that the study represent the closest Finnish data center professionals' vision about the research themes. The results of the study in terms of data center potential in Nordic countries can be, however, generalized for the whole Nordic context due to very similar data center markets in all the Nordic countries. The finding related to the data center trends can be also generalized for even larger context than Nordic countries but only with some extends: For example Nordic data center professionals might see the role of green energy bigger than data center professionals in general since Nordic is so well positioned in the energy issues and data center investors often search for "green solutions" from Nordic. In addition, Nordic data center professionals can also have slightly different vision about the other trends of data center industry than data center industry professionals in general since the Nordic data center market differs from the other

[63] Inner vision means that participants are observing Nordic data center market inside the market by operating there by themselves. Participants in this study are maybe not sharing the same kind of image of the Nordic data center market than people from Central Europe or the U.S.

data center markets with some respects[64]. The findings related to brownfield environment should not be generalized to larger context than Nordic countries since the definition for brownfields was different to the commonly used.

In the qualitative research the researcher himself has an impact on the results. It is more likely that different people would make different kind of conclusions out of the same interview material. Researcher always puts something about himself and his previous experience to the given results. In the interviews the personal chemistry in the interactive situation can also affect on the results. Even with the same questions different interviewees could get different answers.

6.4 Further research

Data center industry is a relatively new industry which still develops in the fast pace. The growth of the data in the future is estimated to be very fast. This growth will be inevitably reflected also in the data center industry. During the research process two new large scale data center projects were announced in northern Europe: Hetzner Online in Finland and Facebook in Ireland (Yle Uutiset 2015b; TechCrunch 2016). Also Apple announced its plan to build a data centers in Denmark and Ireland during the year 2015. Those investments are clear evidence that large data center operators and big Internet companies are constantly searching new locations for their data centers and Northern Europe is well represented in this competition. That fact makes the findings of this research very topical and justifies the need for further research about the topic.

One of the interesting themes for further research would be to investigate other potential uses of brownfield sites in addition to data centers. In this research the potential of brownfield sites was analyzed only by taking into account brownfield sites use as data centers. However, it is clear that only some of the old industrial sites will be harnessed to the data center use in the future and most of the empty brownfields have to find other usage. The problem of many empty brownfield sites in Nordic still exists and other potential uses for those sites should be studied. By widening the clientele to other industries the greater number of potential investors are available. This research introduces only one potential use for brownfield sites but it does not solve the whole “problem”.

Another especially interesting topic for the future research would be to evaluate the role of fiber optic network improvements. In the interviews, the theme rose up many times and many interviewees were speculating the role of fiber cable investments in the data center business. It would be interesting to evaluate for example if the new submarine cable between Finland and Germany changes the competition between Nordic countries by bringing new investments to the whole region or just to Finland. Especially interesting would be to estimate what are the economic impacts of these kind of investments.

Third interesting topic for the further research is the price of the electricity and especially the taxation of electricity. Nordic countries are competing against each other but also against other countries for getting data center investments. One way to differentiate from others is to have cheaper electricity prices. To lower the electricity price for the clients, countries can e.g. change their energy taxation. Finland and Denmark have already lowered the electricity

[64] In the Nordic data center market following things might be emphasized compared with many other data center markets: Ecosystem solutions (district heating is commonly the main source of space heating), free cooling (chilly climate in the region enables to use it all year round).

tax for data centers and Sweden and Norway have planned to do same kind of actions in the future. It would be interesting to study the role of these kind of actions and if they are guiding future investments to Nordic countries as planned.

In this research, many new possible trends of the data center industry were identified. It would be interesting to study how those trends change the data center industry in the future. An especially interesting trend is *the use of excess heat*. The use of excess heat can be a real game changer in the data center industry and all the studies related to its use would be interesting. It would be very interesting i.e. to try to find new innovative ways where data centers excess heat could be used in the future. Some of the very interesting ideas such as fish farming or laundries were already identified in the interviews of this thesis.

Since this thesis was made by using the qualitative research methodology it would be important to validate the results by using quantitative research. Still, conducting such research is still difficult and time consuming since the topic has very little previous academic research and having proper sample of participant would be as difficult as it was also with this thesis. However, conducting the research by concentrating e.g. only on one of the themes of this thesis, some of the difficulties with this thesis could have been avoided. Especially the duration of the study would have been in that case significantly shorter.

7 Summary

The primary goal of this thesis was to estimate the potential of old industrial sites (brownfields) in the data center use especially in the context of Nordic countries. Secondary goals were to find out how *new data center investments could become reality in the Nordic countries* and *what kind of ways could help to attract international investors to target their interest toward the regio*n. In the study new data center business trends were also identified and analyzed, how those trends might affect the future development of the industry. The research was conducted by using three different research methods: Literature review, thematic interviews (empirical part) and observation (=supportive research method).

In the literature review the restructuring development was described and the reasons for the born of brownfield environments presented. The restructuring development and the born of brownfields were explained in this study by putting them in the historical context of Finland. Finland was used as an example country also in the other parts of the study (i.e. when introducing the Nordic data center market). In the literature review data centers were introduced as one potential solution for old industrial sites in the future.

Literature review showed that there is very limited amount of previous academic research about this thesis topic. This means that the study was closest to be exploratory in its nature since no existing theories was used to form hypothesis. Especially data centers potential in the brownfield environment had not been studied in the previous studies. In the literature review the concepts of brownfields and data centers were presented. Data centers were analyzed by introducing their typical characteristics, business models, energy consumption and describing what kind of criteria are used when choosing location for data centers. In addition, the future need for data centers was discussed and the analysis of the current data center market was presented. Old industrial sites (brownfields) were also analyzed considering their use as data centers.

The empirical research of this study was conducted by using thematic interviews as the main data collection method. Interviews were constructed around three main themes: *The use of*

old industrial sites as data centers, promoting data center investments in the Nordic countries and *trends (of data center industry)*. The total of 20 data center industry professionals took part of the interviews. Interviewees came from three different Nordic countries: Finland, Sweden and Iceland, most of the interviewees coming from Finland.

Interviews showed that some of the old industrial sites (brownfields) are suitable for data center use but in many cases there are also difficulties. The common opinion according to the interviews was that some of the brownfield sites are potential for the data center use but usually only with some limitations. In addition, existing constructions rarely bring any added value for the investors.

One of the key findings related to old industrial sites was that sales organizations have to have deep understanding about the strengths of the (brownfield) environment and understand what kind of operators could benefit from the existing constructions (in other words get the maximum benefit from the environment). Existing constructions were seen as a true advantage only if the investor understands the added value it brings to one's own business. Some other positive elements of the brownfield sites were also found in the study: especially the possibility to benefit from the central location was considered as the strength of brownfields. Central location also enables the use of different excess heat solutions.

Several ways for boosting brownfield investments were found in the study. Maybe the most important way to boost brownfield investments is to understand the strengths of the environment and be able to market sites for the right customers. One of the key findings of this study was the idea that brownfield sites have often been marketed only to very limited number of data center operators (usually only to very large data center operators). By taking into account also medium sized data center operators in the marketing the greater number of potential customers are available which can ease finding potential investors. The marketing of brownfield sites should be also generally improved and it is important to get rid of the "one size fits all" type of thinking.

The second theme in the interviews was to identify Nordic countries potential as data center locations and find ways how international data center operators would find Nordic countries interesting investment places for their data centers. The role of the Invest in organization was considered as the most important factor to attract investments. The role of fiber optic network improvements was also considered very central together with the high quality marketing.

According to this study, the biggest advantages of Nordic countries in terms of data center industry are chilly climate (free cooling potential), cheap energy, stable political situation and being economically competitive (cheap operating). Several other advantages of Nordic countries were also identified in the study. Small home markets were considered being the biggest disadvantage of Nordic countries. Also, the latency between Central Europe and Nordic countries was considered as a moderate disadvantage of the region.

The third theme in interviews was the trends of the data centers. According to this study, the biggest trend of the future data center industry is more likely to be green energy. Together with green energy different ecosystem solutions are potential trends of the data center industry. Also the use of excess heat is more likely to increase in the future. Locating data centers in the cold climates and using the free cooling solutions will remain as existing trends of the industry even their importance is maybe somewhat decreasing.

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Appendix 1.

Interview questions (interviews were held both in Finnish and English)

Structure of the interview

Background information:

1. Could you briefly describe your work and organization?
2. What is your experience related to data centers? (Background: What kind of projects have you taken part? What has been your role in those projects?)

1st THEME: Old industrial sites in data center use

**Background information: in this research Brownfield sites mean old industrial sites with no contamination or contamination is very light. Existing buildings are in a good shape, with no need for major renovations (i.e. old paper mills)*

Brownfield vs. Greenfield:

3. What are the main reasons why data center investments are mostly targeted into *Greenfield sites* even there are good *Brownfield sites* available?
4. How old industrial sites *(Brownfields)* should be branded for the data center use? (For what kind of purposes: For small/big DC operators, collocation operators etc.)
5. What kind of acts could rise the attractiveness of *Brownfield sites*? (Relevant information easily assessed, better marketing, incentives for *Brownfield* development etc.)

This question is targeted to data center operators.

1. Why have you build your data center on the old *Brownfield site*, why haven't you?
   a. While searching for a proper site for your data center, did you consider Brownfield Sites? If you answered no, why not? Describe the project briefly.

**In case you are not a data center operator, describe the project/project you have taken part and answer questions from your perspective.*

2th THEME: Promoting data center investment in Finland and Nordic

6. How internet service producers (Google, Facebook, Yandex, Twitter etc.) can be lured to open their data centers in Nordic countries? (Give some examples of the different ways based on your experience or vision)
7. What are the biggest advantages of Nordic countries compared with the rival countries (i.e. Middle Europe)? What are the disadvantages?
   a. Are there some advantages in your country compared with other Nordic countries? What about other Nordic countries, do they have advantages compared with others?
      i. Do you think that Finland's new Baltic Sea cable (fiber cable) will change the competition? Do you think it will help other Nordic countries too?
8. How different actors should contribute data center projects in your country? (municipality, government, sub-regions, companies)
   a. What have been done? What should be done in the future?
   b. Compare your own country with other Nordic countries, what have you done better/worse?
9. There have been some big data center investments in the Nordic countries in the past few years, can you explain why companies have chosen those locations?
   a. How Nordic countries can get more of those investments in the near future? (the next five years)

3th THEME: TRENDS

10. Have you noticed some changes in the data center market?
11. The importance of free cooling has been highlighted in many new data center investments, is this going to be a big trend in the future (air cooling vs water/liquid cooling in the future)?
12. Do you think that data centers are going to grow in their size in the future or are we shifting toward decentralized solutions?
13. Green energy is already a big thing in data centers, how do you see the future (i.e growing importance of green data center solutions)?
14. Are there other trends in the data center market whose importance is growing in the future?

Appendix 2.

Thematic interviews

Key figures of the transcribed interviews:

	Time of interview	Length (min, sec)	Pages	Words	Additional information
1	22.10.2015	72:08	11	3397	
2	23.10.2015	47:18	6	2406	
3	4.11.2015	65:04	9	4447	
4	5.11.2015	84:23	3	844*	
5	6.11.2015	51:09	8	3232	
6	9.11.2015	39:52	5	1911	
7	9.11.2015	69:51	10	4222	
8	13.11.2015	93:32	14	6830	
9	17.11.2015	48:49	8	3243	
10	18.11.2015	65:53	11	5164	
11	19.11.2015	-	3	1058	via email
12	19.11.2015	-	3	1058	via email
13	20.11.2015	55:35	9	4261	
14	30.11.2015	83:10	8	3424	
15	2.12.2015	45:54	5	2404	
16	3.12.2015	58:34	6	3397	
17	4.12.2015	42:47	5	2887	
18	13.12.2015	49:27	8	3561	
19	13.12.2015	49:27	8	3561	
20	21.12.2015	15:57	3	930	
	Median	53:22	8	3320	
	Average	57:41	7	3112	

*Interview was summarized due technical problems. (Original interview would have been about 5000 words)

Appendix 3:
Mind map of the thesis structure